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Literature Review

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Music training and auditory processing skills in children: a systematic review

Treinamento musical e habilidades do processamento auditivo em crianças: revisão sistemática

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ABSTRACT

Purpose: To check the contribution of music training to auditory processing skills in children. **Research strategy:** A search was performed in October 2018, using the descriptors Music, Child, Childhood, Children, Evoked Potentials, Auditory, Auditory Perception, Auditory Processing, using the AND operator. **Selection criteria**: The main research question was: "What has been reported in the scientific literature about the contribution of musical training to auditory processing skills in children?" We selected only controlled clinical trials with the child population, studies published in English, Portuguese and Spanish. **Results:** The search strategy resulted in the selection of ten articles. The studies showed several skills tested and different forms of evaluation. **Conclusion:** Based on the findings, it can be concluded that music training improves auditory processing skills, so the longer the training time, the more these skills are reinforced. Thus, music training is an effective method that can be potentially used in children, both in the development of oral and written communication - to aid in the acquisition of auditory skills - and after acquisition, in order to improve such skills.

Keywords: Evoked potentials, auditory; Music; Auditory processing; Child; Review

RESUMO

Objetivo: Verificar a contribuição do treinamento musical nas habilidades do processamento auditivo em crianças. **Estratégia de pesquisa:** Realizou-se uma busca no mês de agosto de 2018, usando os descritores *Music*, *Child*, *Childhood*, *Children*, Evoked Potentials, Auditory, *Auditory Perception, Auditory Processing,* utilizando o operador *AND.* **Critérios de seleção:** Como questão norteadora, adotou-se a seguinte pergunta: "o que existe na literatura científica sobre a contribuição do treinamento musical nas habilidades de processamento auditivo em crianças?" Após, foram selecionados somente ensaios clínicos controlados na população infantil, estudos publicados em inglês, português e espanhol. **Resultados:** A estratégia de busca resultou na seleção de dez artigos. Os estudos evidenciaram diversas habilidades testadas e diferentes formas de avaliação. **Conclusão:** Com base nos achados, pode-se concluir que o treinamento musical melhora e aprimora as habilidades de processamento auditivo, de forma que quanto maior o tempo de treinamento, mais essas habilidades são reforçadas. Dessa forma, o treinamento musical mostra-se um método eficaz e com potencialidade para ser utilizado em crianças, tanto no período de desenvolvimento da comunicação oral e escrita, para auxiliar a aquisição das habilidades auditivas, como após a aquisição afim de aprimorá-las.

Palavras-chave: Potenciais evocados auditivos; Música; Processamento auditivo; Criança; Revisão

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INTRODUCTION

Hearing is considered one of the most important senses for communication and human relationships[1]. The auditory system consists of a peripheral part and a central part, both of which must be intact for good auditory function. The structures from the external ear to the cerebral cortex are responsible for capturing sounds, simultaneously detecting and transmitting various sound stimuli, thereby allowing and stimulating learning[2].

The capacity of the central auditory system to receive, analyze and interpret sound stimuli is due to auditory processing, whose function is to make sense of acoustic information coming from the environment. Its functioning depends on organic and functional conditions of the auditory system, as well as on the hearer's previous hearing experience[3].

Auditory processing relies on skills to recognize the presence or absence of sound, to identify the source of sound, to share attention between two stimuli, to select an auditory stimulus in the presence of background noise, to distinguish variation in frequency, intensity and duration and to perceive differences and similarities between verbal sounds.

In addition, auditory skills also include identifying acoustically incomplete and distorted but complementary speech sounds in silence; memorizing pitch and duration pattern sequences of one or more sounds; identifying how many sounds are occurring successively considering the interval of silence between them; distinguishing the order of occurrence of sound events and interpreting sound events integrated to other sensory modalities[4].

In order for these auditory skills to become more refined and effective, they need to be stimulated. In this way, music proves to be an excellent means of intensifying these capacities[5]. Learning the language of music requires intense brain activity, since it involves several brain areas at the same time (e.g., perception, from the auditory pathways to processing in the upper brain stem; cognition, comprising memory, attention and executive functions; motor skills and aural skills, as well as capacity to adapt to the occurrence of new stimuli, and new possibilities of response), characterizing brain plasticity[6].

It is known that musical practice develops auditory perception of melody, harmony and rhythm through training on perception of intervals, rhythm, and other musical parameters. Given the tendency towards generalization, these auditory perception skills may increase phonological awareness in tasks involving speech-in-noise recognition, reading, syllable recognition and other language skills[7-9]. In addition, music arouses intense emotions, and it can evoke memories and sensations, involving reward mechanisms such as release of dopamine, which creates a feeling of well-being[10,11].

In this light, considering the benefits of music training and recognizing the importance of hearing skills for full development of child's communication skills, research is needed on the role of music in hearing skills.

OBJECTIVE

The objective of this systematic review was to identify the contribution of music training to auditory processing skills in children.

RESEARCH STRATEGY

This was the main research question: "What has been reported in the scientific literature about the contribution of musical training to auditory processing skills in children?" To answer this question, bibliographical research was carried out in August 2018 on the electronic databases Portal BVS (MEDLINE, IBECS and LILACS) and SciELO, aiming at a systematic review of the literature. The research included studies published until July 2018, without limitation of starting date. The selected descriptors were searched in the *Medical Subject Headings* (MeSH); thus, all terms were accessed in English only. A specific search strategy was developed using the AND operator and the search refiner with the delimiters "*child" OR "adolescent" OR "child, preschool",* using three descriptors at a time: *Music* AND *Child* AND Evoked Potentials, Auditory; Music AND *Childhood* AND Evoked Potentials, Auditory; Music AND *Children* AND *Evoked Potentials, Auditory; Music* AND *Child* AND *Auditory Perception; Music* AND *Childhood* AND *Auditory Perception; Music* AND *Children* AND *Auditory Perception; Music* AND *Children* AND *Auditory Processing; Music* AND *Child* AND *Auditory Processing; Music* AND Childhood AND *Auditory Processing.*

SELECTION CRITERIA

The following inclusion criteria were established for selection and evaluation of the articles: publications up to July 2018; only controlled clinical trials involving humans, with the objective of evaluating the contribution of music training/experience to auditory processing skills in children; and studies published in English, Portuguese and Spanish. Preschool children and children were established as a search limit. Subjects were considered to be children when they were up to 11 years and 11 months old, according to Brazil's Child and Adolescent Statute (ECA)[12]. Studies performed on adult subjects with hearing aids or cochlear implants, as well as publications that were bibliographic reviews, letters to the editor, case-control studies, cohort studies, case studies and studies that did not explore the theme directly, were excluded from the analysis.

The selection of the studies included in this systematic review was based on the recommendation *Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement*[13], which is shown in Figure 1.

DATA ANALYSIS

All articles were examined qualitatively, in accordance with the main research question of the present study and on the inclusion criteria. Quantitative analysis used the protocol based on the checklist of the PEDro international scale[14], translated into Portuguese, which proposes to evaluate the methodological quality of scientific studies. The full text articles were retrieved after the abstracts were read. The results of the analyses were compared among three raters and the classification of the criteria was re-evaluated in a meeting for consensus decision-making.

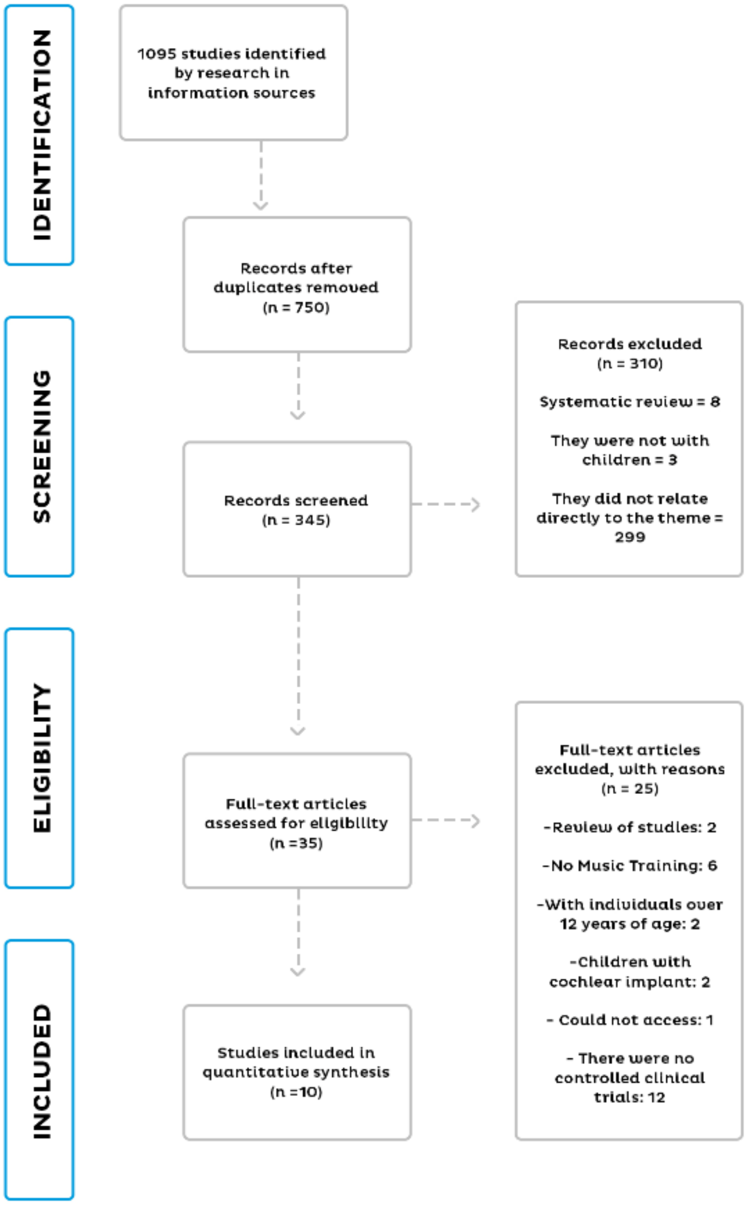

Figure 1. Summary of the process of retrieving the articles selected for the systematic review of the literature

RESULTS

A total of 1,095 articles were identified in the first search: 21 in the SciELO database and 1,074 in the BVS database; 750 articles were excluded because they were repeated. After the titles and abstracts were read, eight out of the 345 remaining articles were excluded because they were systematic reviews; three, because they did not focus on children and 299, because they were not directly related to the theme. In total, 35 articles were selected to be read in full. Based on the analysis, some articles were excluded for different reasons: one because the full text could not be accessed; two because they were a review of studies, two articles addressed training with individuals who used cochlear implants, two studied a population older than 12 years of age, six did not perform music training and 12 were not clinical trials. Thus, ten articles fulfilled the initial inclusion criteria.

Chart 1 shows the main data of the articles, e.g., authors, year of publication, country of origin, objective, procedures, age range, sample size, stimulation time.

Chart 2 shows the skills tested and the results found in each study.

All the selected studies had been written in English. Four out of the ten articles(15,16,18,21) were written in the United States, two(17,20) in Canada, two(8,19) in France, one(7) in Mexico and one(9) in Portugal. As regards year of publication, three(16,17,21) studies were published in 2015 while the others were published between 2004 and 2017.

In terms of sample size, the number of participants ranged from 13 to 46 children (including all children in the control group and the study group). Four(8,9,19,21) articles evaluated 8-year-old children, five(7,15,17,18,20) focused on children aged 3 to 7 years old and only one(16) article did not specify age, and it only uses the expression ‘child’. Time of musical stimulation ranged from 20 sessions to three years of experience.

Chart 1. Characteristics of studies included in the present review

Authors/ Year/Country	Objective	Procedures	Age	Sample size	Stimulation Time
Moyeda (2017)[7] Mexico	To check the effects of training on discrimination of tonal properties of musical stimuli for phonological awareness.	The Primary Measures of Music Audition (PMMA). Phonological Consciousness Battery.	Between 4 years and 6 months to 5 years and 3 months.	28 children.	20 sessions lasting for an average of 25 minutes; 6 evaluation sessions and 14 training sessions.
Habibi et al. (2016)[15]. USA	To investigate the effects of a music training program on the auditory development of children compared to children with sports training and without any training.	Wechsler Intelligence Scale (WISC-II). Tonal perception task. Tone / rhythm discrimination task. Long-latency auditory evoked potentials (stimuli used: violin, piano and pure tones). Electroencephalography (EEG).	At the beginning of the study, they were between 6 and 7 years old.	37 participants: 13 from the group with music training, 11 from the group with sports training and 13 from the group without training.	2 years.
Kraus and Strait (2015)[16]. USA	To investigate the emergence of biological markers of musicianship in children and adolescents who received musical training.	Frequency following response (FFR).	Not specified. The authors cited 'children and adolescents' only.	26 children with musical training.	1 - 3 years.
Moreno et al. (2015)[17]. Canada	To evaluate immediate and long-lasting effects of music training and second-language learning in early childhood.	Electroencephalography (EEG). Mismatch Negativity (MMN). Late Discriminative Negativity (LDN). Stimuli: vowels and musical notes.	Between 4 and 6 years of age.	36 participants, 18 in each group. After 1 year, 16 children from the French group and 14 from the music group returned for follow-up testing.	Two 1-hour sessions per day for 20 days.
Strait et al. (2013)[18]. USA	To determine the neural impact of music training by comparing auditory brainstem responses (ABRs) with speech stimuli in quiet and noisy backgrounds.	Peabody Picture Vocabulary Test. Frequency Following Response (FFR).	Between 3 and 5 years of age.	32 children. 18 musicians and 14 nonmusicians.	At least twelve consecutive months up to the test date.
Moreno and Besson (2005)[19]. France	To check the influence of music training on pitch processing.	Electroencephalography (EEG).	8 years.	20 children, 10 of whom received music training and 10 received painting training.	8 weeks.
Shahin et al. (2004)[20]. Canada	To assess whether Auditory Evoked Potential components are sensitive to musical expertise in children and, if so, which components are affected.	Electroencephalography (EEG).	4 and 5 years.	Cross-sectional sample: 24 children without musical training. Sample training: 13 children: 7 with music training and 6 without training.	1 year.
Slater et al. (2015)[21]. USA	To check the influence of music training on speech-in-noise perception.	Wechsler Scale. The Hearing in Noise Test (HINT).	8 years.	46 children. Group 1: 19 Group 2: 27	Group 1: 1-year training. Group 2: 2-year training.
Chobert et al. (2012)[8]. France	To check the influence of music training on preattentive processing of syllable duration and voice onset time.	Wechsler Intelligence Scale for Children (WISC-IV). Mismatch Negativity (MMN). Voice Onset Time (VOT). Electroencephalography (EEG).	8 - 10 years.	24 children. 12 in Group with music training and 12 in the Control Group.	12 months.

Subtitle: PMMA = The Primary Measures of Music Audition; WISC = Wechsler Intelligence Scale for Children; EEG = Electroencephalography; FFR = Frequency following response; MMN = Mismatch Negativity; LDN = Late Discriminative Negativity; HINT = The Hearing in Noise Test; VOT = Voice Onset Time

Chart 1. Continued...

Authors/ Year/Country	Objective	Procedures	Age	Sample size	Stimulation Time
Moreno et al. (2008)[9]. Portugal	To assess the influence of music training on language skills in children.	Wechsler Intelligence Scale for Children (WISC-III). Digit Span. Specific reading tests in Portuguese. Electroencephalography (EEG).	8 years.	32 children. 16 in the music group and 16 in the control group.	9 months.

Subtitle: PMMA = The Primary Measures of Music Audition; WISC = Wechsler Intelligence Scale for Children; EEG = Electroencephalography; FFR = Frequency following response; MMN = Mismatch Negativity; LDN = Late Discriminative Negativity; HINT = The Hearing in Noise Test; VOT = Voice Onset Time

Chart 2. Skills tested and results achieved

Author/Year	Skills Tested	Results
Moyeda (2017)[7].	Tone discrimination. Phonological awareness.	The study group showed improved discrimination of tone stimuli and greater phonological awareness, unlike the control group, although not significantly. The effects of tonal training are not conclusive on tone discrimination of musical stimuli or phonological awareness.
Habibi et al. (2016)[15].	Tone and rhythm discrimination.	The children in the study group showed improved ability to detect changes in the tone environment and accelerated auditory processing maturation, which were not found in the other two comparison groups.
Kraus and Strait (2015)[16].	Speech in noise. Reading.	Children who had received musical training showed better reading and speech-in-noise perception, as well as faster neural responses. Outcomes indicate that many of musicians' auditory-related biological enhancements emerge with training and may promote the acquisition of language skills, including in at-risk populations.
Moreno et al. (2015)[17].	Perception of musical notes and vowels.	Soon after training, there was enhancement of LDN but not of MMN. After 1 year of training: Training-induced ERP responses were attenuated but persistent for both groups. Group with music training showed an effect in musical note and vowel perception tasks, but the effect in the group with French training remained only in one task, indicating a stronger effect of music training.
Strait et al. (2013)[18].	Speech in noise.	Children with music training showed faster neural responses to speech in noise and quiet conditions, as well as a reduction in quiet-to-noise-delays. Test-retest data indicate that an additional year of continued music training further protects musicians' neural responses from the degrading effects of background noise.
Moreno and Besson (2005)[19].	Pitch discrimination.	There was no difference between the groups before the training sessions. Afterwards, analysis of ERPs showed significant differences between the music and the painting groups. There was a decrease in amplitude after music training only in the study group. The difference was greater for the parietal regions. As the children of the music training group were particularly pitch-trained, processing may have become more automatic. Such decrease would consequently stem from automation of underlying processes which, therefore, require fewer and fewer neurons. The results showed some evidence of an influence of music training on pitch processing in language after just eight weeks of music training.
Shahin et al. (2004)[20].	Pitch discrimination.	Children with music training presented better responses in comparison to the control group. They obtained P2 enhancement specifically for the sound of the practice instrument. AEPs differed between children with music training and control children as young as 4 years of age, and the differences reflect a specific musical experience.
Slater et al. (2015)[21].	Speech in noise.	Speech-in-noise perception improved significantly in the group with 2 years of training and was significantly higher in the group with 1 year of training in the third evaluation. The study provided longitudinal evidence that two years of musical training is associated with modest but clinically significant gains in the ability to understand speech in noise.
Chobert et al. (2012)[8].	Preattentive processing. Syllable duration	No differences were found between groups before auditory training. Enhanced preattentive processing of syllable duration and VOT, as reflected by greater MMN amplitude, but not of vowel frequency, was found after only 12 months of training in the music group only.
Moreno et al. (2008)[9].	Language skills. Reading. Perception of pitch changes in speech.	Children with music training showed improved reading and pitch processing skills.

Subtitle: LDN = *Late Discriminative Negativity*; MMN = Mismatch Negativity; ERP = Event Related Potential; AEPs = Auditory Evoked Potentials; VOT = Voice Onset Time

Table 1. Methodological classification assessed by the PEDro scale

Selected Studies	PEDro Scale Analysis			
	External validity (Max = 1)	Internal validity (Max = 8)	Interpretable results (Max = 2)	Total score (Max = 11)
Moyeda[7]	1	4	2	7
Habibi et al.[15]	1	2	2	5
Kraus and Strait[16]	0	3	2	5
Moreno et al.[17]	1	4	2	7
Strait et al.[18]	1	3	2	6
Moreno and Besson[19]	1	3	1	5
Shanin et al.[20]	1	1	2	4
Slater et al.[21]	1	3	2	6
Chobert et al.[8]	1	3	2	6
Moreno et al.[9]	1	4	2	7

All the studies evaluated children before and after music training and contained a control group. Among the procedures, the Wechsler Intelligence Scale for Children was used in four studies for a previous assessment of the participants. Electroencephalography (EEG), *Frequency Following Response* (FFR) and *Mismatch Negativity* (MMN) were the most common procedures, and behavioral tests were also used in most studies.

The PEDro scale was used to check scientific evidence in the ten studies. The aim of the scale is to help researchers identify whether the criteria could be fulfilled by the clinical outcomes of the therapies applied. The scale has a checklist with 11 items that investigate internal validity, external validity and results that can be interpreted statistically. Table 1 shows the methodological classification evaluated by the PEDro scale and the score of the articles in each item of the scale.

DISCUSSION

Children undergo numerous developmental changes, and childhood allows for greater neural plasticity as influenced by experience[22]. It is known that music training influences the functional and structural development of the brain and improves auditory skills, as well as cognitive processes such as memory, attention and intelligence[16,23-25]. This review confirms previous reports in the literature, which highlighted the benefits of music training to auditory processing skills.

Three studies[16,18,21] used figure-ground perception to test auditory processing skills. The findings showed that children with normal hearing and typical development, with at least one year of music training, showed better performance in reading and speech-in-noise perception, when compared to children without auditory training. Three articles[7,9,16] investigated how music relates to the language skills of phonological awareness and reading. For phonological awareness, positive effects of musical training were found for initial syllable identification and rhyme identification[7]. The results showed that 8-year-old children improved their reading skills, particularly when grapheme-phoneme correspondence was complex[9].

There were very different outcomes depending on type of training applied. In four studies[15,16,18,20], the participant children were trained in a musical instrument; one of them [20] was based on the Suzuki Method, whose principle is the idea that children learn to play a musical instrument in the same way that they acquire their mother tongue. Thus, the method is based on imitation and repetition of musical notes, rhythmic and melodic patterns only by ear, while musical notation is used later[26]. Two other studies[8.9] reported using the Kodály and Orff methods. The aim of the Kodály Method is to promote musical literacy and bring music to people's daily lives through songs, especially folk songs. Its methodology includes music reading and writing, perception and rhythm[27]. The Orff Method integrates music and movement, and it is based on improvisation with the use of percussion and singing[28].

Regardless of the method in use, it was found that music training in all studies approached musical parameters, height, intensity, duration and timbre and the three basic elements of music: rhythm, melody and harmony.

Among the procedures in use, EEG was the most common test; it was described in six studies[8,9,15,17,19,20], followed by Frequency Following Response (FFR)[16,18] and Mismatch Negativity (MMN)[8,17], both of which were reported in two articles. EEG is an evaluation method that captures spontaneous brain activity at the cortical level through electrodes placed on the scalp[29], while FFR is an excellent instrument for assessing neural response to speech sounds, providing access to sound processing at a very precise level of detail[16].

Another procedure was MMN, which investigates the abilities of sound discrimination, auditory memory and involuntary attention, because it is a long-latency auditory evoked potential that captures automatic brain response[30]. One study reported an improvement in MMN in children aged 8 and 10 years old[8], while no significant changes were found in another study with children aged between 4 and 6 years old[17]. These data confirm findings of other investigations that MMN is closely linked with age and time of exposure to music. Continued music training in childhood progressively increases sound discrimination and attention[22,31-34].

It should be noted that six articles included in this review are considered to be Randomized Clinical Trials (RCTs)[7-9,16,17,20], since they are experimental studies, and the population was randomly assigned to the study and control groups. RTCs are considered to be the gold standard for determining the effect of an intervention because they can provide unbiased assessments[35]. They are also one of the most powerful tools for collecting evidence of health care and clinical practice[36].

Through evaluation of the PEDro scale[14], it was found that few articles fulfilled the criteria of the checklist, especially as far as internal validity is concerned. Thus, the overall score of the studies was relatively low because there was no random allocation of subjects nor blinding of subjects, therapists and assessors. Blinding of subjects and therapists was considered to be unfeasible, because regardless of the type of training in use, be it music, painting or sport, the trainers had to know how to instruct the subjects so that the assessors could analyze the objectives of the studies.

CONCLUSION

Based on the findings, it can be concluded that music training enhances auditory processing skills; the longer the training lasts, the more these skills are reinforced. Thus, music training is an effective method that can be potentially used in children to develop their oral and written communication, assist them with the acquisition of auditory skills, and help them improve such skills after acquisition.

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