FACTORS IN CHILDHOOD AND ADOLESCENCE THAT MAY INFLUENCE THE AUDITORY PROCESSING: A SYSTEMATIC REVIEW

Fatores na infância e adolescência que podem influenciar o processamento auditivo:revisão sistemática

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ABSTRACT

There is consensus in literature of the importance of the auditory system to the development of oral and written language. The Auditory Processing Disorder refers to difficulty on processing of auditory information.The aim of this systematic literature review was to analyze which factors occurring in childhood and teens may influence auditory processing, not necessarily being the cause or consequence of the disorder. Two researchers used PubMed and SciELO databases independently. The descriptors used were auditory processing; auditory perception; children; teens, in various combinations. Among the 205 articles identified, 30 articles matched the inclusion criteria and were analyzed. Only two studies showed positive factors influencing auditory processing skills: the influence of musical stimulation in infancy and the use of methylphenidate as a treatment for attention deficit/hyperactivity disorder. The influences are, mostly, negative to auditory processing, emphasizing the relationship of the disorder with dyslexia, learning difficulties, specific language impairment, low socioeconomic level, attention deficit/hyperactivity disorder, preterm birth, phonological disorders, visually impairment, mouth breathing, stuttering, otitis media, cleft lip and palate, anemia, exposure to metallic mercury, obstructive sleep apnea-hypopnea syndrome, stroke, children on social vulnerability and dysphonic children. Auditory Processing proves sensitive to the negative influences of environmental, chemical factors, socioeconomic status, language disorders, auditory, and neurological. Exposure to music and the use of methylphenidate were the only factors with positive influence on auditory processing.

KEYWORDS: Hearing Tests; Auditory Perception; Child; Adolescent

INTRODUCTION

The auditory function, and its close relationship of interdependence with language, is still surrounded by ontogenetic mysteries, such as the differential sensitivity of the auditory system regarding the better audibility in the pitches of formulation of speech[1]. These authors also point out that there are still many issues to be solved, such as biological, mechanical, neurochemical and electrical mechanisms.

The proper functioning of the peripheral and central auditory system is fundamental for the development of oral and written language. This system can be divided into two parts: the peripheral auditory system and the central auditory system, which are interrelated. The peripheral auditory system comprises the structures of the outer, middle and internal ear and the vestibulocochlear nerve, which are responsible for the collection, transmission and transduction of the sound wave and the processing in the cochlea and cochlear portion of the vestibulocochlear nerve, which is located in the temporal region of the head. The cochlea, in children without

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disorders, is already functional at birth, unlike the central auditory system, which is immature; the development of the auditory perception is a prolonged event beginning in the prenatal stage, and suffers interference in its development in childhood and adolescence[2].

The auditory system is responsible for processing the information performed by several integration centers with the functions of detecting and discriminating sound, separating background noise, understanding and recognizing sounds as familiar, among others. This entire process involves the transmission of auditory information through the fibers of the cranial nerve VIII to the cochlear nuclei, brainstem, thalamus and auditory cortex[3].

The term "Auditory Processing Disorder" (APD) is referred to by the American Speech-Language-Hearing Association[4](ASHA) as the difficulty in processing auditory information in one or more auditory skills, and it represents a limitation in the transmission, analysis, organization, processing, preparation, storage and/or recovery, and use of information from an acoustic event that is not attributed to hearing loss or intellectual deficit. Individuals with suspected APD, according to ASHA, often exhibit behavioral characteristics of difficulty in understanding spoken language in a situation of competitive noise, frequently ask to repeat the spoken information, have difficulty in paying attention, are easily distracted, have difficulty in following complex auditory commands, have difficulty in locating sounds and have learning disabilities. However, these characteristics are not unique to APD and can be found in other diagnoses, such as language disorder, Attention Deficit Hyperactivity Disorder (ADHD) and Asperger Syndrome. Therefore, APD must be understood as a hearing disorder that can be isolated or associated with other cortical alterations, such as learning disorder, ADHD, among others. However, not all learning and language difficulties and communication deficits are due to the Auditory Processing Disorder.

The evaluation of the auditory processing can be done through behavioral and electrophysiological tests. Behavioral tests are conducted in a soundproof booth through a battery of tests, which assess the central auditory function, but they also demand cognition, attention, memory and language.

The APD can be aggravated in an unfavorable acoustic environment with repercussions on academic skills. The main school complaints in relation to the children with the disorder are that they: "are distracted," "have their hads in the clouds," "just listen when they want," "do not pay any attention to the teacher," "cannot learn" [5]. The author also describes they can be caused by neuromorphological lesions, neurological disorders or delayed auditory pathway maturation of the central nervous system and brain; however, there are no epidemiological studies indicating the prevalence of causes. This way, further studies are needed for a broader understanding of the subject.

The knowledge of the factors that can influence the APD is relevant as a warning for a proper investigation of the medical history of the individual (anamnesis), as well as the development of prevention and health promotion actions.

The aim of this study was to analyze which factors may influence the auditory processing skills in childhood and adolescence, which are not classified as a cause or a consequence of the disorder.

METHODS

An electronic search was performed in the SciELO and PUBMed databases by two researchers independently, in September 2013. The choice of these databases is justified by the significant number of studies, with a Brazilian sample, which is the focus of this research.

The research was conducted with the crossing of the following keywords and their corresponding terms in English: *processamento auditivo* (auditory processing)*; percepção auditiva* (auditory perception)*; crianças* (children)*; adolescentes* (adolescents). We found 170 articles in each database, amounting to 340; after the elimination of duplicate studies on the databases, we obtained a total of 205 full articles. We added on an Excel spreadsheet the data related to the title of the study, the journal, year of publication, age group, characterization of the study groups and the tests applied.

Then, we selected the relevant studies using as criteria for inclusion: 1. original articles; 2. analytical observational studies (cross-sectional of control group); 3. studies that used procedures in the methodology that could allow the evaluation of the auditory processing through behavioral methods standardized for the Portuguese version [6]and 4. studies that contained in their sample children and adolescents aged between 4 and 19 years (according to the World Health Organization - WHO) with normal hearing, with some condition at risk for APD (Figure 1). Exclusion criteria: 1. studies with children and adolescents users of implants or hearing aids; 2. studies that did not use behavioral tests as an assessment method; 3. studies without a control group; 4. studies with more than 10 years of publication; 5. studies with a sample that was not composed of children and adolescents. After applying the criteria described, 30 articles were selected for analysis; their studies were published in the period from 2005 to 2013. The selection of the behavioral assessment battery of tests of the AP determined the skills to be evaluated. Most studies did not evaluate all the skills involved, thus, we did not examined the efficiency of the neural processing at different levels within the NSCA. The tests used are classified as diotic, monotic and dichotic.

Diotic tests are those in which auditory stimuli are presented simultaneously on both ears, in free field[7]; they are: Sound Location Test and Sequential Memory for Verbal (SMVS) and Non-verbal (SMNV) Sounds Test, which assessed the abilities of location and memory for sounds in sequence, and are part of the Simplified Evaluation of the Auditory Processing.

The monotic tests are those that use the main message and the competitive message in the same ear, simultaneously[7]. The monotic tests used by the studies analyzed were: Pediatric Speech Intelligibility Test (PSI) with Ipsilateral Competitive Message (ICM) and Synthetic Sentence Identification Test (SSI) with Ipsilateral Competitive Message (ICM) and the Filtered Speech (FS) and Speech-in-Noise (FR) Tests.

The dichotic tests are those that use the main stimulus in one ear and the competitive message in the contralateral ear simultaneously through an earphone[7]. They are: Dichotic Listening Test (DL), Dichotic Test of Staggered Spondaic Word (SSW), Non-verbal Dichotic Test (NVD) and Binaural Fusion Test (BF).

In addition to these, we also used tests to assess the temporal processing, being they: Random Gap Detection Tests (RGDT), Pitch and Duration Pattern Tests (PPS and DPS) and Gap-in-Noise (GIN).

LITERATURE REVIEW

Following the inclusion criteria, of the 30 selected articles, 19 (63%) presented sample composed of children and adolescents, 9 (30%) of children and two articles (7%) of adolescents, as illustrated in the diagram (Figure 1).

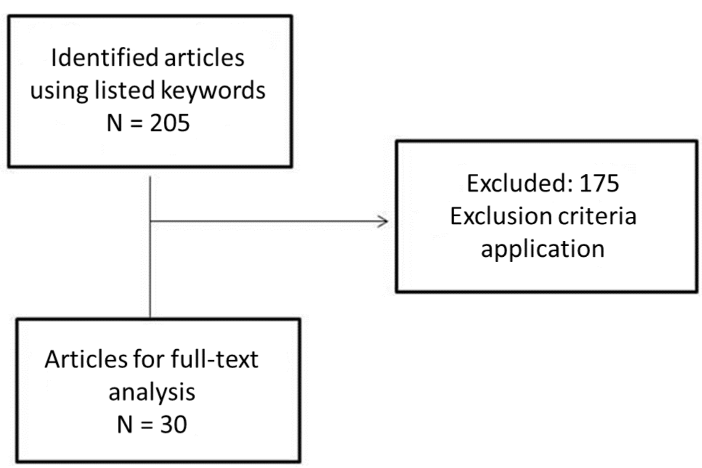

Figure 1 – Explanatory diagram of the selection process of the articles

The results of the studies are grouped according to the similarities of the factors and alterations addressed, being they: external factors, neurological alterations, structural and/or functional alterations, alterations in oral language and alterations in written language.

The studies that addressed the influence of external factors in the auditory skills, which involved the socioeconomic status, chemical agents, psycho-active agents and music, are presented in Figure 2:

Article	Sample	Evaluation	Results	Conclusion
A1. (Balen, Boeno and Liebel, 2010)	Age: 6 to 11 years; G1: high socioeconomic status; G2: average socioeconomic status; G3: low socioeconomic status.	Tests of Random Gap Detection (RGDT) and Gap-in-Noise (GIN).	There was a statistically significant difference between the groups in both tests.	There was influence of the socioeconomic status on the temporal resolution in the two tests performed.
A2. (Cavadas, Pereira and Mattos, 2007.	Age: 7 to 15 years; G1: with ADHD using Methylphenidate; G2: no attention deficit, with learning disorders; G3: no attention deficit, no learning disorder.	Tests of Sound Location, Sequential Memory for Verbal and Non-verbal Sounds, Speech-in-Noise and Staggered Spondaic Word (SSW).	G1 with performance similar to G3 in the CAP tests; G2 showed the worst performance, G3 presented the best performance.	The CAP tests did not allow the differentiation of ADHD children; use of Methylphenidate was associated with improved performance in the tests with ADHD children, but it does not allow the establishment of a relationship.
A3. (Dutra, Monteiro and Câmara, 2010)	Age: 7 to 17 years; G1: workers in the burning of gold-mercury amalgam or residents near the burning areas; G2: no history of exposure to mercury.	Tests of Sound Location, Sequential Memory for Verbal and Non-verbal Sounds, Speech-in-Noise, Pitch Pattern and Staggered Spondaic Word (SSW).	Statistically significant differences between the groups for the tests of Pitch and Duration Pattern and SSW.	Adolescents exposed to metallic mercury showed lower performance to those not exposed, for most tests.
A4. (Escalda, Lemos and França, 2011).	Age: 5 years; G1: with musical experience; G2: no musical experience.	Tests of Sound Location, Sequential Memory for Verbal and Non-verbal Sounds.	Performance on the tests of Sound Location and Sequential Memory for Non-Verbal Sounds had relationship with the musical experience of the sample.	The musical experience promotes the improvement of auditory skills of five-year-old children.
A5. (Murphy et al., 2012).	Age: 7 to 10 yeas / 11 to 16 years; G1: in situation of social vulnerability; G2: no complaints.	Tests of Pediatric Speech Intelligibility (PSI), Speech-in-Noise, Non-verbal Dichotic, Dichotic Listening and Sequential Memory for Verbal and Non-verbal Sounds.	Significant differences were found between the groups for most tests; G1 with statistically worse performance than G2 for all tests, except for PSI.	Worst performance of G1 for the CAP behavioral tests.

Figure 2 – Influence of external factors on the Auditory Processing:Socioeconomic Status, Chemical Agents, Psychoactive Agents and Music

Researchers investigated the possible influence of the socioeconomic status on the auditory processing ability of temporal resolution of students[8], and divided them into three groups: high, average and low socioeconomic status. There was a statistically significant difference in performance between the groups, and the best performance was from the high socioeconomic status group, followed by the average status and the worst performance was from the low status. The authors observed that the socioeconomic status can influence the temporal resolution; however, they point out that it cannot be concluded that the low socioeconomic status generates alterations in the temporal resolution, since they observed performances that deviated from normality in this ability in all groups; the sample was not separated by parameters of normality or presence of auditory processing alterations, and the results were similar to the study that investigated aspects related to the auditory processing in groups of children and adolescents in situation of social vulnerability[9] andit wasobserved that these subjects had a significantly worse performance compared to the control group. The auditory skills evaluated in these studies were: temporal resolution, auditory closure, figure-ground and memory for sounds in sequence. The influence of the socioeconomic status on the development of the language was the second most variable studied in recent years, which shows a better language performance in children from families with higher income, which, according to a systematic review, suggests that the family income influences the amount of stimuli provided and consequently the development of the child[10]. This way, considering that cognition, memory and language are necessary for the performance of the AP tests, it is confirmed the relationship of the socioeconomic status factor with the results found in the assessment.

In addition to socioeconomic factors, chemical agents present in society, such as metallic mercury, also demonstrated an effect on the Auditory Processing. Exposure to metallic mercury, from artisanal gold mining areas, is referred to as a health issue with effects on the central nervous system that affect the substantia nigra and the occipital and temporal lobes. Thus, significant differences were observed in adolescents exposed to mercury in behavioral tests compared to those who had no exposure, with statistically significant losses in the tests of SMNV, PPS and DPS and SSW, in Portuguese, with alterations in the perception of short sounds and sounds in sequence[11]. Therefore, the abilities altered in this study were the memory for sounds in sequence, temporal ordering and figure-ground. Another chemical substance present in the studies is the methylphenidate that is used as a drug prescribed to ADHD; the use of this substance was associated with improvement in the test results of these individuals, and the abilities of sound location, memory for sounds in sequence, auditory closure and figure-ground were evaluated. The authors attributed this result to the improvement in the attention, which does not allow the establishment of a relationship between the use of the medicine and the improvement in the performance[12].

Apart from the external factors already mentioned, the musical experience had a positive interference in the auditory processing; researchers investigated the relationships between musical experience and auditory processing skills and phonological awareness[13]. Children with musical experience had a superior performance on the memory ability for sounds in sequence, evaluated in verbal and non-verbal sequential memory tests with four instruments, with performance similar to that expected for six years old children, determined by their musical experience. The musical experience has been highlighted not only in the contribution to the auditory processing, as elucidated, but demonstrates interference on the overall development of children, with positive relations between communicative, metalinguistic and listening skills[14].

Neurological alterations, such as the Attention Deficit Hyperactivity Disorder (ADHD), Cerebrovascular Accident (CVA) and Prematurity, with possible influences in the AP, were also studied and are presented in Figure 3:

The ADHD showed negative interfere in the auditory processing skills; children with ADHD showed statistically worse performance compared to the groups of children in the dyslexia study and control group without alterations. The skills altered were auditory closure, figure-ground and temporal ordering, which suggests a close relationship between the attention skills and the auditory processing skills evaluated[15].

Two studies examined the presence of auditory processing disorder in children born prematurely[16,17]. The first study verified a correlation between the results of the evaluation of the auditory processing and the behavioral assessment carried out at 12 months, thus demonstrating the relationship between the ability of temporal ordering and the ability of sound location. The second study used the RGDT to evaluate the ability of temporal resolution. Both studies found significant differences between the group of children born prematurely and the control group (at term).

The cerebrovascular accident also interfered in the hearing ability of the figure-ground, and the attention performance was worse in the study group, composed of children and adolescents diagnosed with CVA. The auditory attention was evaluated by the binaural separation, NVD and consonant-vowel tests, and also by the integration, SSW and dichotic listening tests, being possible the verification of the relationship between the CVA and the deficit in selective attention in both tasks with verbal and non-verbal stimuli[18].

The Auditory Processing Disorder can also be influenced by structural and/or functional alterations in childhood, such as Cleft Lip and Palate, Oral Breathing, Dysphonia and Visual impairment, according to the studies indicated in Figure 4.

Article	Sample	Evaluation	Results	Conclusion
A6. (Abdo, Murphy and Schochat, 2010).	Age: 7 to 12 years; G1: no complaints of alterations of the AP or delay in the development of oral or written language; G2: with dyslexia; G3: with ADHD.	Tests of Speech-in-Noise, Dichotic Listening and Pitch Pattern.	G3 with the worst result in all tests, followed by G2 and G1.	Close relationship between the attention skills and the CAP skills evaluated.
A2. (Cavadas, Pereira and Mattos, 2007).	Age: 7 to 15 years; G1: with ADHD using methylphenidate; G2: no attention deficit, with learning disorders. G3: no attention deficit, no learning disorder.	Tests of Sound Location, Sequential Memory for Verbal and Non-verbal Sounds, Speech-in-Noise, Duration Pattern and Staggered Spondaic Word (SSW).	G1 with performance similar to G3 in the CAP tests; G2 showed the worst performance G3 showed the best performance.	The CAP tests did not allow the differentiation of ADHD children; use of Methylphenidate was associated with improved performance in the tests with ADHD children.
A7. (Elias and Moura-Ribeiro, 2012).	Age: 7 to 16 years; G1: children with CVA; G2: healthy children.	Tests of Non-verbal Dichotic, Consonant-Vowel, Dichotic Listening, Duration Pattern and Staggered Spondaic Word (SSW).	In the Non-verbal Dichotic test, it was observed a greater difficulty with the ear contralateral to the lesion on free attention and difficulty in the directed stages. In the Consonant-Vowel test, there was some difficulty in focusing the attention on the directed stages. In the tests of Dichotic Listening and SSW, ipsilateral, contralateral and bilateral deficits were found.	Children with CVA showed deficits in the ability of selective attention in dichotic tasks, with verbal and non-verbal stimuli.
A8. (Fortes, Pereira and Azevedo, 2007).	Age: 5 to 6 years G1: born at term; G2: born prematurely.	RGDT	G1 with lower detection thresholds of time intervals than G2.	Those born prematurely differ from those born at term regarding the auditory behavior of temporal resolution.
A9. (Gallo et al., 2011).	4 to 7 years; G1: born prematurely; G2: born at term.	Tests of Sound Location, Sequential Memory for Non-verbal Sounds, Speech-in-Noise, PSI and Dichotic Listening.	In G1, 93.75% showed altered CAP, with difference between the groups for the tests of Temporal Ordering, PSI and Speech-in-Noise.	Children born prematurely had worse results than children born at term, in the CAP evaluation.

Figure 3 – Influence of the neurological alterations on the Auditory Processing:ADHD, CVA and Prematurity

A10. (Arnautetal, 2011).	Age: 4 to 8 years; G1: with dysphonia; G2: no complaints for vocal disorders.	Tests of Sound Location and Sequential Memory for Verbal and Non-verbal Sounds.	Similarity between the groups in the tests of Sound Location and Sequential Memory for Verbal Sounds; G1 with the worst performance in test of Sequential Memory for Non-verbal Sounds.	Dysphonic children show alterations in the location or temporal ordering skills; temporal ordering for non-verbal sounds is worse in the dysphonic group.
A11. (Correa et al., 2011).	Age: 8 to 12 years; G1: with mouth breathing; G2: with nasal breathing;	Filtered Speech, Pitch Pattern Sequence and SSW Tests.	G1 with the worst performance in the organizational, auditory integration, auditory closure and temporal pattern skills.	Children with Mouth Breathing show a lower performance on the CAP skills than children with normal breathing pattern.
A12. (Lemos et al., 2007).	Age: 7 years; G1: with cleft lip and palate; G2: without the anomaly.	Dichotic Listening Test.	G1 presented a lower percentage of success than G2 in AO; girls showed worse results than boys.	The application of only one CAP test was not conclusive, being considered as a poor study group to study the effectiveness of the test.
A13. (Moraes et al., 2011).	Age: 7 to 10 years; G1: with cleft lip and palate and history of otitis media; G2: with cleft lip and palate and no history of otitis media;	Tests of Sound Location, Sequential Memory for Verbal and Non-verbal Sounds, Auditory Fusion, PSI, Speech-in-Noise, SSI, Non-verbal dichotic, SSW and Dichotic Listening.	G1 with the worst performance in the tests of Sound Location, Sequential Memory for Verbal and Non-verbal Sounds, Auditory Fusion; G2 with the worst performance in the tests of PSI, Speech-in-Noise and SSI.	A central alteration was found in 100% of the children in both groups studied.
A14. (Santos, 2011).	Age: 8 to 12 years; G1: visually impaired; G2: with normal vision.	Tests of Sound Location, Sequential Memory for Verbal and Non-verbal Sounds, Speech-in-Noise, Dichotic Listening, Duration Pattern and RGDT.	G1 and G2 with similar results in tests of Sound Location, Sequential Memory for Non-verbal Sounds and Speech-in-Noise; in the other tests, G1 had lower performance.	G1 with lower development than G2 in the CAP evaluation.
A15. (Zilliotto et al., 2006).	Age: 5 to 11 years; G1: mouth breathing and normal polysomnography; G2: mouth breathing and altered polysomnography; G3: no otorhinolaryngologic complaints.	Tests of Sound Location, Sequential Memory for Verbal and Non-verbal Sounds and Dichotic Listening.	G2 with worse performance than G3 in the Dichotic Listening Test.	Presence of Sleep Apnea-Hypopnea Syndrome was positively related to the CAPD.

Figure 4 – Influence of structural and/or functional alterationson the Auditory Processing:Cleft Lip and Palate, Oral Breathing, Dysphonia and Visual Impairment

In evaluating the AP of dysphonic children, the auditory abilities of Location and Temporal Ordering were evaluated, and it was observed a difference between the study and control groups regarding the sequential memory for non-verbal sounds. The study showed that, for dysphonic children, the sound location ability improved with the increased age[19].

In relation to the study which examined the presence of the AP disorder in children with mouth breathing, a difference was found in the auditory performance of these children, with statistically significant differences in the skills of figure-ground, auditory closure and temporal ordering[20], since the respiratory system has influence on the cerebral oxygenation. The study that evaluated children with obstructive sleep apnea-hypopnea syndrome identified changes in the auditory processing skills of this population, in particular the ability of figure-ground, relating them as arising out from the same mechanisms that lead to neurocognitive alterations, in general; the authors also highlight the increase of the paediatric population with partial or complete obstruction of the upper airways, which cause intermittent disruptions of the normal ventilation during sleep[21].

The relationship of visual impairment with central auditory processing was analyzed by researchers who found unfavorable, but not statistically significant, performance in children with visual impairment in relation to the control group, both in the audiometric assessment and in the battery of tests of the Auditory Processing, in the skills of figure-ground and temporal ordering and resolution[22].

Cleft lip and palate was related to auditory skills and evaluated in two studies. In a study investigating the hearing of 20 children with cleft lip and palate with and without a history of otitis media, the authors found a poor performance on most tests in both groups. The population with a history of otitis media showed worse results in the assessment of the auditory processing in the skills of sound localization, memory for sounds in sequence and auditory integration when compared with the population with no history of otitis media; this population had the worst performances in the auditory closure and figure-ground abilities[23]. Similarly, in another study, a lower performance was found on the figure-ground ability of children with cleft lip and palate through the Dichotic Listening Test compared to children without it[24].

The auditory processing of individuals with oral language alterations (stuttering, specific language impairment (SLI), Phonological Disorder) was also investigated (Figure 5) and, despite showing the interference of these alterations in certain central auditory skills, most studies are singular in the aspect studied.

The ability of temporal ordering of children with Specific Language Impairment – SLI – was altered and correlated to the language processing; thus, the higher the impairment in the temporal auditory processing found in these children, the worse the performance in tasks of high syntactic complexity[25]. Children who stutter also showed worse performance in the ability of temporal ordering with statistically significant difference when compared to children who do not stutter, which indicates a relationship between this oral language disorder and the auditory processing[26]. In relation to the interface between the phonological disorder and the auditory processing skills, the studies confirm that children with a speech disorder show lower performance compared to children without phonological disorders, and the main altered abilities are: temporal resolution, location, memory for sounds in sequence, figure-ground and auditory closure[27-30].

Finally, we observed that the majority of studies sought to know the influences of the disorders of the written language (dyslexia, learning disabilities) in the auditory skills, being dyslexia the main focus – Figure 6.

The studies presented were diversified in relation to the aspects and/or factors correlated with the AP and its skills. There was an agreement about the poor performance, in the evaluation of the auditory processing, of children with reading/writing disorders and dyslexia when compared to children without disorders, especially in temporal processing skills[15,31-37]. Children without the diagnosis of dyslexia, but with school difficulties were assessed through the tests of PSI, NVD and SSW; children with school problems showed worse performance on all the tests applied to the three age groups, which suggests a delay in the maturation of figure-ground skills of students with difficulties[38]. Another study that applied the tests of LS, SMVS, SMNV and PSI found a higher frequency of alterations in the group of children with difficulty, in all tests, but with no statistically significant differences[39].

In summary, three studies (10%) found no relationship between the variable studied and the Processing Disorder and concluded that further research is needed in the area for a better investigation of this relationship. In one of these studies, the justification is based on the fact that it performed only one test, which limited the result. In the second study, it was observed a limitation because of the application of few tests to verify the relationship between the variable and the disorder. Despite having applied diotic, monotic and dichotic tests,

A16. (Attoni, Quintas and Mota, 2010).	Age: 5 to 7 years; G1: no speech impairment; G2: with phonological disorder.	Tests of Sound Location, Sequential Memory for Verbal and Non-verbal Sounds, PSI, Speech-in-Noise, Dichotic Listening and SSW.	All children of the G2 presented alterations in the CAP, unlike children with no speech impairment.	Changes in the CAP are closely linked to speech difficulties.
A17. (Attoni, Quintas and Mota, 2010).	Age: 5 to 7 years; G1: with phonological disorder; G2: with normal speech development.	Tests of PSI, Speech-in-Noise, SSW and Dichotic Listening.	G1 with alterations in the assessment of the CAP and G2 with normal results.	Children with phonological disorders have alterations in the CAPD.
A18. (Fortunato-Tavares et al., 2009).	Age: 8 to 10 years; G1: with typical language development; G2: diagnosed with SLI.	Pitch Pattern Sequence Test.	G2 had a performance in the TPF outside the reference values.	The Pitch Pattern Test is positively correlated with the abilities of syntactic complexity.
A19. (Muniz et al., 2007).	Age: 6 to 9 years; G1: diagnosed with phonological disorder; G2: no phonological disorder or other oral language alteration.	RGDT	94.5% of children of the G1 presented altered results, with a statistically significant difference between the groups.	Children with phonological disorders may present temporal processing alteration, thus requiring more time to detect intervals of time between auditory stimuli than children without complaints.
A20. (Quintas et al., 2010).	Age: 5 to 7 years; G1: with phonological disorder; G2: no phonological disorders.	Tests of Sound Location, Sequential Memory for Verbal and Non-verbal Sounds, Dichotic Listening, Binaural Fusion and SSW.	G1 with worse results in the CAP evaluation.	Significant relationship between the performance of the CAP and the presence of phonological disorders.
A21. (Silva, Oliveira and Cardoso, 2011).	Age: 9 to 12 years; G1: with persistent developmental stuttering; G2: no complaints or signs of neurological/ psychiatric disorders, speech, hearing, language and/or learning difficulties.	Pitch and Duration Pattern Test.	G2 with superior performance in the two tests applied.	Relationship between stuttering and CAPD.

Figure 5 – Influence of alterations of oral language on the Auditory Processing:Stuttering, SLI, Phonological Disorder

A5. (Abdo, Murphy and Schochat, 2010).	Age: 7 to 12 years; G1: no complaints of alterations of the CAP or delay in the development of oral or written language; G2: with dyslexia; G3: with ADHD.	Tests of Speech-in-Noise, Dichotic Listening and Pitch Pattern.	G3 with the worst result in all tests, followed by G2 and G1.	Close relationship between the attention skills and the CAP skills evaluated.
A22. (Boscarioletal, 2010).	Age: 8 to 14 years; G1: diagnosed with developmental dyslexia; G2: no neuropsychological alterations.	RGDT	Statistically significant difference between the groups, with worse performance for G1; this group presented perisylvian polymicrogyria in the neurological evaluation.	Students with developmental dyslexia may exhibit alterations in the auditory temporal processing, with impairment in the phonological processing. Malformation of the cortical development can be the anatomical substrate of the disorders.
A23. (Capellini, Germano and Cardoso, 2008).	Age: Mean of 10 years and 4 months; G1: diagnosed with dyslexia; G2: with satisfactory school performance.	Tests of Sequential Memory for Verbal and Non-verbal Sounds, Sound Location, PSI, Dichotic Listening and SSW.	There was a statistically significant difference between the groups in most tests.	Auditory processes interfere directly in the perception of acoustic, temporal and sequential aspects of sounds for the formation of a stable phonological representation.
A24. (Murphy & Schochat, 2009).	Age: 9 to 12 years; G1: with dyslexia; G2: no school complaints.	Tests of Ordering and Discrimination of Pitch and Duration Pattern.	G1 with statistically worse performance in all tests.	It is not possible to say that the poor performance of children with dyslexia in the CAP tests is related to the poor performance in reading and phonological awareness tasks.
A25. (Neves & Schochat, 2005).	Age: 8 to 10 years; G1: with complaints about school difficulties; G2: no complaints about school difficulties;	PSI, Speech-in-Noise, Nonverbal Dichotic and SSW Tests.	G1 showed the worst performance on all applied tests and for the three age groups.	Delay in the maturation of the CAP abilities in the group of children with educational difficulties.
A26. (Oliveira, Murphy and Schochat, 2012).	Age: 9 to 12 years; G1: with dyslexia; G2: no complaints related to reading and school performance.	Tests of Pitch Pattern, Dichotic Listening and Speech-in-Noise.	G1 with the worst performance on the Pitch Pattern and Dichotic Listening tests.	Children with dyslexia have alterations in their auditory skills of temporal processing and figure-ground.
A27. (Pelitero, Manfredi and Schneck, 2010).	Age: 8 to 12 years; G1: with average or higher performance in the test of school performance; G2: with lower performance in at least one of the subtests.	Tests of Sound Location, Sequential Memory for Verbal and Non-verbal Sounds and PSI.	Higher frequency of alterations in G2 in relation to G1, in all tests, but without statistically significant differences	No statistically significant differences were found between the groups.
A28. (Sauer et al., 2006).	8 to 12 years; G1: diagnosed with dyslexia; G2: no learning complaints.	Tests of Dichotic Listening, Staggered Spondaic Word and Non-verbal Dichotic.	There were statistically significant differences between the groups in all tests.	Children with dyslexia have alterations in the Central Neurological Processing.
A29. (Simões & Schochat, 2010).	7 years to 12 years and 11 months; G1: with dyslexia; G2: with CAPD.	Tests of Speech-in-Noise, Dichotic Listening and Pitch and Duration Pattern.	G1 with greater probability of alteration in the tests of Speech-in-Noise and Dichotic Listening.	Subjects with dyslexia show different patterns of CAPD, with greater variation in the tests that evaluate the temporal processing than in other skills.
A30. (Wiemes et al., 2012).	7 to 14 years; G1: with P300 latency above 335ms; G2: with P300 latency below 335ms.	Tests of SSW and Speech-in-Noise.	70% of G1 with auditory dysfunction in the Speech-in-Noise test and 100% in the SSW test.	Alterations in the CAP were found in children with reading and writing disorders, with P300 latency above 335ms.

Figure 6 – Influence of alterations of written language/learning on the Auditory Processing:Dyslexia, Learning Disabilities

the battery of tests selected did not evaluate every auditory skill.

Of the 30 selected articles, only two (7%) used all categories of tests mentioned; seven (23%) used only Temporal Resolution tests, three (10%) used only dichotic tests and two (7%) utilized only diotic tests, i.e. they did only the Simplified Evaluation of the Auditory Processing. None of the studies performed only monotic tests. Moreover, six studies (20%) applied only one test.

The most used test was the Dichotic Listening Test, which was used in 15 articles, i.e. 50%. Some tests were used only in one study, as in the case of the Binaural Fusion test and the SSI test.

The SSW test was used in some studies with population in the age group below 8 years; however, its use is recommended after 9 years of age given the effect of neuromaturation in health individuals[5].

The auditory processing skills have shown a strong correlation with tasks that assess neuropsychological skills, with an emphasis on concentrated attention, perception of faces, oral language and memory, which is justified by the sharing of cognitive skills[40].

The diagnosis of auditory processing disorder requires a multidisciplinary team, given its complexity, numerous causes and repercussions on the performance of children and adolescents. The studies analyzed show that several factors may influence the auditory processing skills assessed and it is difficult to say if the factors studied and the poor performance in the proposed tests demonstrate a primary dysfunction, or are comorbidities, in particular when they involve the relationship between auditory and cognitive skills, as shown in this study.

The studies presented are mostly unique in the factors studied, and the positive and negative influences found cannot be generalized. Similarly, we cannot say that the subjects evaluated present disorders analyzing only the results of some tests applied in isolation. Despite the limitations of these studies, we emphasize their relevance because they brought attention to some presented factors that can influence the Auditory Processing. It is necessary a continuous effort to confirm the findings that can be associated with auditory processing disorders, aiming to enhance the clinical and educational actions of the professionals involved with this population.

CONCLUSION

The Auditory Processing is sensitive to the negative influence of various factors: environmental conditions, socioeconomic conditions, language disorders (phonology, writing, stuttering), peripheral auditory alterations (otitis media), chemicals (metallic mercury) and neurological changes (Dyslexia, ADHD). Exposure to music was the only positive influence on the auditory processing skills, and the use of methylphenidate for ADHD children indicated improvement in the retest, but it does not allow the establishment of a relationship between the use of the medicine and the improvement in performance.

RESUMO

Há consenso na literatura da importância do sistema auditivo para o desenvolvimento da linguagem oral e escrita. O Distúrbio do Processamento Auditivo refere-se à dificuldade no processamento de informações auditivas, não sendo devido à perda auditiva, nem ao déficit intelectual. O objetivo desta revisão sistemática da literatura foi analisar quais fatores ocorridos na infância e adolescência podem influenciar no processamento auditivo, não necessariamente sendo a causa ou consequência do distúrbio. Foram utilizadas as bases SciELO e PUBMed por duas pesquisadoras de forma independente. Os descritores utilizados foram: processamento auditivo; percepção auditiva; crianças; adolescentes, em combinações variadas. Dentre os 205 artigos identificados, 30 artigos corresponderam aos critérios de inclusão, sendo analisados. Apenas dois estudos demonstraram fatores positivos influenciando a habilidade do processamento auditivo: a influência da estimulação musical na infância e o uso de Metilfenidato, como tratamento doTranstorno de Déficit de Atenção e Hiperatividade. As influências são, em sua maioria, negativas ao processamento auditivo, destacando-se a relação do distúrbio com a dislexia, dificuldades escolares, distúrbio específico de linguagem, nível socioeconômico baixo, Transtorno de Déficit de Atenção e Hiperatividade, nascimento pré-termo, desvio fonológico, deficiência visual, respiração oral, gagueira, otite média, fissura labiopalatina, anemia, exposição ao mercúrio metálico, síndrome da apnéia/hipopnéiaobstrutiva do sono, acidente vascular cerebral, crianças em vulnerabilidade social e crianças disfônicas. O Processamento Auditivo mostra-se sensível as influências negativas de fatores ambientais, químicos, condições socioeconômicas, alterações de linguagem, auditivas, e neurológicas. A exposição à música e o uso de Metilfenidato foram os únicos fatores, com influência positiva nas habilidades do processamento auditivo.

DESCRITORES: Testes Auditivos; Percepção Auditiva; Criança; Adolescente

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