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Original Article

Artigo Original

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Temporal auditory aspects in children with poor school performance and associated factors

Aspectos temporais auditivos de crianças com mau desempenho escolar e fatores associados

Keywords

Hearing
Auditory Perception
Hearing Tests
Underachievement
Speech, Language and Hearing Sciences

ABSTRACT

Purpose: To investigate the auditory temporal aspects in children with poor school performance aged 7-12 years and their association with behavioral aspects, health perception, school and health profiles, and sociodemographic factors. **Methods:** This is an observational, analytical, transversal study including 89 children with poor school performance aged 7-12 years enrolled in the municipal public schools of a municipality in Minas Gerais state, participants of Specialized Educational Assistance. The first stage of the study was conducted with the subjects' parents aiming to collect information on sociodemographic aspects, health profile, and educational records. In addition, the parents responded to the Strengths and Difficulties Questionnaire (SDQ). The second stage was conducted with the children in order to investigate their health self-perception and analyze the auditory assessment, which consisted of meatoscopy, Transient Otoacoustic Emissions, and tests that evaluated the aspects of simple auditory temporal ordering and auditory temporal resolution. Tests assessing the temporal aspects of auditory temporal processing were considered as response variables, and the explanatory variables were grouped for univariate and multivariate logistic regression analyses. The level of significance was set at 5%. **Results:** Significant statistical correlation was found between the auditory temporal aspects and the variables age, gender, presence of repetition, and health self-perception. **Conclusion:** Children with poor school performance presented changes in the auditory temporal aspects. The temporal abilities assessed suggest association with different factors such as maturational process, health self-perception, and school records.

Descritores

Audição
Percepção Auditiva
Testes Auditivos
Baixo Rendimento Escolar
Fonoaudiologia

RESUMO

Objetivo: investigar os aspectos temporais auditivos de crianças de 7 a 12 anos de idade com mau desempenho escolar e a associação com aspectos comportamentais, percepção de saúde, perfil escolar e de saúde e fatores sociodemográficos. **Métodos:** trata-se de estudo observacional analítico transversal com 89 crianças de 7 a 12 anos de idade, com mau desempenho escolar das escolas públicas municipais de uma cidade do interior de Minas Gerais, participantes dos Atendimentos Educacionais Especializados. A primeira etapa da pesquisa foi realizada com os pais para coleta de informações sobre questões sociodemográficas, perfil de saúde e vida escolar. Além disso, os pais preencheram o *Strengths and Difficulties Questionnaire (SDQ)*. A segunda etapa foi realizada com as crianças para investigação da autopercepção de saúde e da avaliação auditiva que constou da meatoscopia, Emissões Otoacústicas Transientes e testes que avaliam os aspectos temporais auditivos de ordenação temporal simples e resolução temporal. Foram consideradas como variáveis respostas os testes que avaliam os aspectos temporais auditivos e as variáveis explicativas foram agrupadas para realização da análise de regressão logística uni e multivariável, considerando o nível de significância de 5%. **Resultados:** foi encontrada associação com significância estatística entre aspectos temporais auditivos e as variáveis idade, gênero, presença de reprovação e autopercepção de saúde. **Conclusão:** as crianças com mau desempenho escolar apresentaram alterações dos aspectos temporais auditivos. As habilidades temporais avaliadas sugerem associação a diferentes fatores como: processo maturacional, autopercepção de saúde e histórico escolar.

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INTRODUCTION

Hearing, in association with motor and cognitive aspects, is crucial for the development of oral and written language. The process of acoustic stimulus transformation from its perception to its understanding and interpretation is called auditory processing[1].

Auditory temporal processing refers to the processing of acoustic stimuli overtime. It aids in the perception and identification of stimuli which are presented in a rapid succession of time[2,3]. The abilities related to the temporal aspects of auditory temporal processing include masking, integration, ordering, and resolution.

The auditory ability of simple temporal ordering refers to the processing of two or more auditory stimuli in a given ordering of time occurrence. This auditory behavior allows the individual to distinguish the correct order of a sequence of sounds[4].

Temporal resolution refers to the ability of the auditory system to detect, within a sound stimulus, rapid and sudden changes, that is, it is the lower limit to resolve time required for perception of different acoustic events[2,3].

According to the literature, temporal ordering and resolution abilities affect the perception and understanding of human speech, therefore constituting a prerequisite for language abilities[5]. A change in auditory perception can cause problems in the development of speech and language, as well as in the learning and socialization of children[6]. A longitudinal study conducted with 236 German children, who were monitored for twenty months, found that auditory temporal order thresholds have a causal influence on literacy development[7].

There is evidence that the temporal aspects are the basis of auditory processing, especially regarding speech perception of sound, duration and ordering of phonemes and identification of words[4,8], and must therefore be considered for diagnosis[2].

In addition to issues related to auditory temporal processing, socioeconomic characteristics and social risks can exert great influence on the cognitive and language development of children[9]. Studies have shown that children with learning difficulties often present emotional, behavioral[10], and temporal auditory impairments[6,11].

Thus this study aimed to investigate the auditory temporal aspects in children with poor school performance aged 7-12 years and their association with behavioral aspects, health perception, school and health profiles, and sociodemographic factors.

METHODS

This is an observational, analytical, transversal study including 89 children with poor school performance aged 7-12 years enrolled in the municipal public schools of a small municipality in Minas Gerais state, participants of Specialized Educational Assistance (AEE)[12]. The AEE is a service of special education that identifies, prepares, and organizes educational and accessibility resources considering the children's special needs. To be attended by this service, children should necessarily present poor school performance according to teacher assessment.

The students and parents who agreed to participate in the study signed an Informed Consent Form (ICF). Exclusion criteria were as follows: not undergoing all assessments proposed; presenting incomplete questionnaires; evidence or history of neurological, cognitive and/or psychiatric disorders; previous diagnosis of hearing loss; earwax buildup in the external auditory meatus; and absence of transient otoacoustic emissions (TOE).

Sample calculation was performed considering a margin of error of 9%, 95% confidence interval, and 50% prevalence, noting the range of outcomes of interest. A sample of 90 children (Figure 1) was estimated based on the criteria presented.

Data collection was conducted in a multidisciplinary institution. A sound-pressure level meter (Instrutherm, DEC-490 model) was used for evaluation of the sound pressure levels in the assessment room. The equipment calibration was within

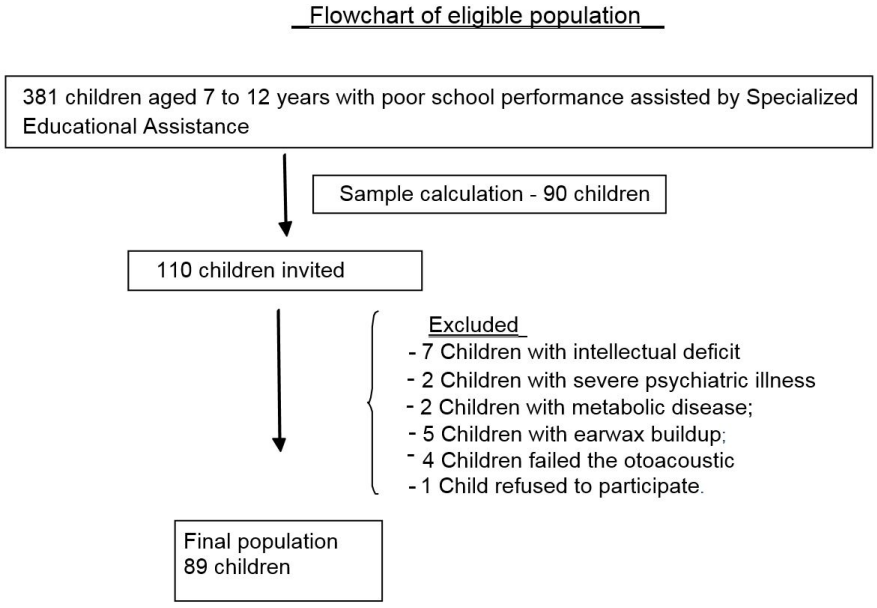

Figure 1. Flowchart of the population composition process

the validity period. Measurements were taken according to the procedures of the Brazilian NBR 10151 standard[13]. The average noise level was 50 dB(A). It is within the recommended range, which states that noise level in the classroom should vary from 40 dB(A) to 50 dB(A)[14].

First, the parents were interviewed to collect information on school records and health factors, in addition to demographic issues, including the Brazil Economic Classification Criterion (CCEB)[15]. For this classification, we considered the educational level of the head of household and the family's possessions, classified from A1 to E, where A refers to the greatest and E to the smallest purchasing power. In addition, the parents completed the Strengths and Difficulties Questionnaire (SDQ)[16]. This questionnaire aims to screen children behavior, emotions, and interpersonal relationships. It consists of 25 items divided into five subscales, namely, prosocial behavior, hyperactivity/inattention, emotional symptoms, conduct problems, and peer relationship problems. Also, parents/guardians were surveyed on the perceived health of their children. This single question on health perception was also answered by the children with the following response options: very good, good, fair, bad, and very bad.

On the auditory assessment, following the inspection of the external auditory meatus performed with Heine Mini 3000 equipment, children with bilateral otoacoustic emissions were subjected to tests to assess the auditory temporal thresholds of simple ordering and resolution. Otoacoustic emissions were measured using OtoRead - Standard and Clinical, version 7.65.01 (Interacoustics).

Simple auditory temporal ordering was evaluated by the verbal working memory test (VWMT) and non-verbal sound sequence memory test (NVSSMT). The VWMT is a dichotic test in which participants have to repeat three different sequences with four syllables (/pa/, /ta/, /ka/, /fa/) emitted by the assessor, with no visual cues. In the NVSSMT, participants have to identify the correct presentation order of three different sequences produced by four instruments (agogo bell, bell, rattle, coconut), also with no visual cues. Temporal resolution was assessed by the random gap detection test (RGDT). This test consists in the emission of pairs of pure tones at frequencies of 500, 1000, 2000, and 4000 Hertz, with intervals between the two tones ranging from 0 to 40 ms. The child was instructed to respond gesturally when hearing the two tones. The adopted evaluation criteria have been suggested in the literature[17-19].

A two-channel audiometer, PAC-2000 (Acustica Orlandi) and headphones, TDH-39 (ANSI, 1969), coupled with a Micro System AZ1050 (Philips), with fixed presentation intensity of 65 dBNS was used to assess temporal resolution. The calibration procedure met the standards of the ISO 389, Part 1; IEC 60645, Part 2; and ISO 8253, Parts 1, 2, and 3. The results of this test were discarded owing to difficulties in the understanding or execution of an assessment.

The results of the three tests utilized to evaluate the temporal auditory aspects (NVSSMT, VWMT and RGDT) were used as response variables. The tests were classified as appropriate or inappropriate according to standardization proposed in the literature[17-19]. The explanatory variables were grouped into behavioral aspects, health perception, school and health profiles, sociodemographic factors, and health history.

For data analysis, responses from the instruments were organized and scanned into a database, and then verified. A descriptive analysis of the frequency distribution was conducted for the categorical variables, whereas an analysis of central tendency and dispersion was performed for the continuous variables. The collected data were scanned and analyzed using the software programs Excel and STATA 11.0.

Logistic regression was used to verify the statistical correlation between dependent and explanatory variables. In the first phase, univariate logistic regression analysis at 5% significance level was used to compare children with altered test results with those with no alteration in the same test. In the second phase, all variables associated with the auditory temporal processing tests with $p \leq 0.20$ in the univariate analysis were adjusted for age and gender and included in the multivariate model. Sequential deletion of variables was performed starting with those of lower statistical significance, and only the variables associated with the temporal processing tests with $p \leq 0.05$ remained in the final model.

The magnitude of association was measured by odds ratio, and 95% confidence intervals were obtained.

This project was analyzed and approved by the Research Ethics Committee of the institution, process n. CAAE 18683013.6.0000.5149.

RESULTS

Analysis of the tests performed showed that 46% of the 89 children who took the non-verbal sound sequence memory test (NVSSMT) had altered test scores; 88 children took the verbal working memory test (VWMT), resulting in a 36% mismatch; and most (79%) of the 76 children evaluated by the Random Gap Detection Test (RGDT) showed altered test scores (Table 1). It was possible to observe a variation in the number of participants who were able to take the proposed tests, especially regarding the RGDT, with 15% of the sample not taking the test satisfactorily.

As for the behavioral features, it was found that most students presented negative emotional symptoms, hyperactivity/inattention, conduct problems, and peer relationship problems. In addition, most of the children presented altered SDQ impact supplement, that is, the difficulties identified by the parents may indicate impairment in leisure activities, friendships, and academic achievement. Negative health perception (fair, poor,

Table 1. Descriptive analysis of the auditory temporal processing tests

Result	NVSSMT[a]	VWMT[b]	RGDT[c]
	n (%)	n (%)	n (%)
Normal	48 (54.0)	56 (64.0)	16 (21.0)
Altered	41 (46.0)	32 (36.0)	60 (79.0)
Total	89 (100.0)	88 (100.0)	76 (100.0)

Caption: [a] Non-verbal sound sequence memory test; [b] Verbal working memory test; [c] Random Gap Detection Test

or very poor) was reported by 26% of the children and 13% of the parents. The univariate analysis of the sample showed that only health self-perception had positive statistical correlation with simple temporal ordering of non-verbal sounds ($p = 0.01$) (Table 2).

By analyzing the data regarding the health and school profiles (Table 3), it was observed that 72% of the parents had complaints with respect to their children's written language, with other speech complaints being reported less frequently. In general, these students were enrolled in school before they were four years old, and had no difficulties adjusting to it. However, 23% of them had at least one failure in their school records. At the time of evaluation, most children did not present medical diagnosis, nor used prescription medication. The univariate analysis showed no statistically significant correlation between these variables and auditory temporal processing.

Regarding the sociodemographic aspects and health history, parental education was predominantly illiteracy or elementary school level and children had two or more siblings and belonged to the C class. In this study, most children were born at full term, presented adequate neuropsychomotor development, and had never been hospitalized till the time of the survey. In the univariate analysis, the variables economic status and age presented significant correlation, p=0.05 and p=0.02, respectively (Table 4).

Table 5 shows the final model of multivariate analysis adjusted for age and gender. The variable age showed statistically significant correlation with all the hearing tests evaluated in this study. There was a positive correlation between the RGDT and the variables health self-perception and gender. Significant statistical correlation was found between the VWMT and school failure and between the NVSSMT and health self-perception.

DISCUSSION

In this study, children with poor school performance presented, in most cases, alterations in the auditory temporal aspects for both temporal ordering and temporal resolution. This finding corroborates other studies that show that children

Table 2. Description of the study population and analysis of correlation between auditory temporal and behavioral aspects and health perception

Explanatory variables	n (%)	NVSSMT[a]		VWMT[b]		RGDT[c]	
	Total 89 (100)	OR[d](CI[e] 95%)	P-value	OR[d] (CI[e] 95%)	P-value	OR[d] (CI[e] 95%)	P-value
Emotional symptoms							
Normal	29 (33.0)	1		1		1	
Altered	59 (67.0)	0.84 (0.34-2.06)	0.71	0.92 (0.36-2.34)	0.88	1.48 (0.46-4.75)	0.51
Conduct problems							
Normal	34 (38.6)	1		1		1	
Altered	54 (61.4)	1.97 (0.81-4.79)	0.13	0.90 (0.36-2.21)	0.82	0.76 (0.23-2.51)	0.66
Hyperactivity/Inattention							
Normal	37 (42.0)	1		1		1	
Altered	51 (58.0)	1.41 (0.59-3.33)	0.43	1.71 (0.69-4.23)	0.24	0.76 (0.24-2.38)	0.64
Peer relationship problems							
Normal	39 (44.3)	1		1		1	
Altered	49 (55.7)	1.66 (0.70-3.93)	0.24	1.60 (0.65-3.93)	0.21	1.18 (0.38-3.60)	0.76
Prosocial behavior							
Normal	76 (86.4)	1		1		1	
Altered	12 (13.6)	1.82 (0.52-6.31)	0.34	1.88 (0.54-6.47)	0.31	0.58 (0.13-2.59)	0.48
SDQ total							
Normal	27 (30.7)	1		1		1	
Altered	61 (69.3)	1.06 (0.42-2.65)	0.90	0.98 (0.38-2.53)	0.97	1.22 (0.36-4.10)	0.75
SDQ impact supplement							
Appropriate	22 (25.6)	1		1		1	
Inappropriate	64 (74.4)	2.14 (0.76-5.99)	0.15	1.00 (0.36-2.77)	0.99	0.64 (0.15-2.61)	0.54
Notion of children health according to parents							
Very good	11 (12.5)	1		1		1	
Good	65 (73.9)	0.43 (0.11-1.63)	0.28	0.95 (0.25-3.64)	0.95	1.14 (0.20-6.35)	0.88
Fair/poor/very poor	12 (13.6)	0.40 (0.75-2.21)	0.29	1.45 (0.26-8.12)	0.67	0.76 (0.09-6.04)	0.78
Health self-perception							
Very good	28 (31.5)	1		1		1	
Good	38 (42.7)	2.25 (0.79-6.39)	0.13	1.09 (0.38-3.11)	0.86	0.51 (0.11-2.24)	0.37
Fair/poor/very poor	23 (25.8)	4.68 (1.42-15.46)	0.01*	1.75 (0.55-5.61)	0.34	0.33 (0.07-1.57)	0.16

Caption: [a] Non-verbal sound sequence memory test; [b] Verbal working memory test; [c] Random Gap Detection Test; [d] Odds Ratio; [e] Confidence interval; *p≤0.05

Table 3. Description of the study population and analysis of correlation between auditory temporal and behavioral aspects and health perception

Explanatory variables	n (%)	NVSSMT[a]		VWMT[b]		RGDT[c]	
	Total 89 (100)	OR[d] (CI[e] 95%)	P-value	OR[d] (CI[e] 95%)	P-value	OR[d] (CI[e] 95%)	P-value
School starting age							
Aged 4 years or older	60 (70.0)	1		1		1	
Aged 5 years or older	26 (30.0)	1.12 (0.44-2.84)	0.81	1.23 (0.47-3.25)	0.66	2.11 (0.53-8.38)	0.29
Failures							
No	67 (77.0)	1		1		1	
Yes	20 (23.0)	1.31 (0.47-3.58)	0.59	2.43 (0.85-6.91)	0.09	1.61 (0.40-6.47)	0.50
Difficulty in adapting at school							
Yes	39 (45.3)	1		1		1	
No	47 (54.7)	0.94 (0.39-2.22)	0.89	0.97 (0.39-2.37)	0.95	0.73 (0.23-2.31)	0.60
Speech complaint							
Yes	43 (49.0)	1		1		1	
No	45 (51.0)	0.76 (0.32-1.78)	0.54	0.96 (0.40-2.34)	0.93	0.90 (0.29-2.74)	0.86
Oral language complaint							
Yes	26 (30.0)	1		1		1	
No	62 (70.0)	0.61 (0.24-1.56)	0.31	0.71 (0.27-1.84)	0.49	0.24 (0.04-1.17)	0.08
Written language complaint							
Yes	63 (72.0)	1		1		1	
No	25 (28.0)	0.58 (0.22-1.51)	0.27	0.95 (0.36-2.51)	0.92	0.68 (0.20-2.32)	0.54
Voice complaint							
Yes	7 (8.0)	1		1		1	
No	81 (92.0)	0.60 (0.12-2.88)	0.52	0.75 (0.15-3.65)	0.73	0.58 (0.64-5.35)	0.64
Hearing complaint							
Yes	20 (23.0)	1		1		1	
No	68 (77.0)	0.60 (0.22-1.66)	0.33	0.63 (0.23-1.77)	0.39	0.19 (0.02-1.63)	0.13
Auditory processing complaint							
Yes	39 (44.0)	1		1		1	
No	49 (56.0)	0.54 (0.23-1.27)	0.16	0.58 (0.24-1.42)	0.24	0.98 (0.32-3.02)	0.98
Clinical diagnosis							
Yes	14 (16.0)	1		1		1	
No	75 (84.0)	2.43 (0.69-8.51)	0.16	1.03 (0.31-3.42)	0.96	3.44 (0.91-12.9)	0.07
Prescription medication							
Yes	24 (27.0)	1		1		1	
No	64 (72.0)	0.97 (0.37-2.52)	0.96	1.23 (0.45-3.32)	0.68	1.22 (0.36-4.10)	0.75

Caption: [a] Non-verbal sound sequence memory test; [b] Verbal working memory test; [c] Random Gap Detection Test; [d] Odds Ratio; [e] Confidence interval

with learning difficulties present changes in their temporal auditory processing[6,11,20-22].

Parents reported a high number of behavioral manifestations, such as hyperactivity/inattention, conduct problems, peer relationship problems, and emotional symptoms. Children with these characteristics may have difficulty in interacting socially, maintaining attention, and developing communication skills[23]. One study compared children with and without auditory behavior changes and found that those with auditory processing disorders showed greater psychosocial difficulties in several areas compared with those without disorders[24]. In that study, however, there was no statistically significant correlation between the behavioral aspects and changes in the auditory temporal aspects in children with poor school performance. Nevertheless, it is worth considering that the processing tests used in the aforementioned study were different from those of the current research.

In our study, children belonging to the C class were 3.87 times more likely to present changes in the simple temporal ordering ability for verbal sounds in sequence when compared with children belonging to the B class. Therefore, worsening in the socioeconomic classification increases the chances of a child to present alterations in simple temporal ordering. It should be emphasized that, in the present study, we did not investigate the socioeconomic level; instead, an economic classification which estimates the purchasing power of families was analyzed. A national study assessed the influence of socioeconomic status in the temporal resolution of 44 children from public and private schools aged six to 11 years and found that this variable can influence this hearing ability, that is, the worse the economic classification, the worse the performance in tests that evaluate temporal processing[25]. Another study reported that children with low socioeconomic status presented comparatively worse performance especially with respect to tests of perception,

Table 4. Description of the study population and analysis of correlation between auditory temporal and sociodemographic aspects and health history

Explanatory variables	n (%)	NVSSMT[a]		VWMT[b]		RGDT[c]	
	Total 89 (100)	OR[d] (CI[e] 95%)	P-value	OR[d] (CI[e] 95%)	P-value	OR[d] (CI[e] 95%)	P-value
Maternal education							
Illiterate/elementary school	53 (62.0)	1		1		1	
Medium/higher education	32 (38.0)	1.15 (0.47-2.79)	0.76	0.53 (0.20-1.38)	0.19	1.12(0.35-3.56)	0.84
Paternal education							
Illiterate/elementary school	41 (56.0)	1		1		1	
Medium/higher education	32 (44.0)	1.92 (0.74-5.00)	0.18	1.04 (0.39-2.72)	0.94	1.83 (0.49-6.83)	0.37
Number of siblings							
None	9 (10.0)	1		1			
One	33 (37.0)	2.18 (0.48-9.82)	0.31	0.86 (0.17-4.22)	0.86	1	
Two or more	47 (53.0)	0.64 (0.15-2.76)	0.55	1.40 (0.30-6.39)	0.66	1.27 (0.20-8.10)	0.79
Economic classification							
B	18 (21.0)	1		1		1	
C	56 (64.0)	0.47(0.16-1.42)	0.18	3.87 (0.99-15.03)	0.05*	2.02 (0.55-7.33)	0.28
D	13 (15.0)	0.39 (0.09-1.73)	0.22	3.12 (0.58-16.74)	0.18	1.81 (0.27-12.01)	0.53
Gender							
Male	61 (68.5)	1		1		1	
Female	28 (31.5)	0.82 (0.33-2.04)	0.68	1.50 (0.59-3.78)	0.39	3.24 (0.66-15.88)	0.15
Age							
7-8	48 (54.0)	1		1		1	
9-10	26 (29.0)	0.44 (0.16-1.91)	0.11	0.60 (0.21-1.66)	0.33	0.40 (0.11-1.46)	0.17
11-12	15 (17.0)	0.17 (0.04-0.72)	0.02*	0.49 (0.13-1.78)	0.28	0.39 (0.08-1.75)	0.22
NPMD[f]							
Appropriate	65 (75.0)	1		1		1	
Inadequate	22 (25.0)	0.97 (0.36-2.58)	0.95	0.54 (1.88-1.59)	0.27	1.36 (0.33-5.55)	0.66
Gestational age							
Term	79 (92.0)	1		1		1	
Preterm	7 (8.0)	1.74 (0.36-8.49)	0.48	1.81 (0.27-12.01)	0.25	0.47 (0.07-2.90)	0.42
Hospitalization							
Yes	40 (46.0)	1		1		1	
No	47 (54.0)	0.98 (0.42-2.30)	0.98	0.88 (0.36-2.15)	0.79	1.52 (0.49-4.67)	0.46

Caption: [a] Non-verbal sound sequence memory test; [b] Verbal working memory test; [c] Random Gap Detection Test; [d] Odds Ratio; [e] Confidence interval; [f] Neuropsychomotor development; *p≤0.05

Table 5. Final model of multivariate analysis

Explanatory variables	NVSSMT[a]		VWMT[b]		RGDT[c]	
	OR[d] (CI[e] 95%)	P-value	OR[d] (CI[e] 95%)	P-value	OR[d] (CI[e] 95%)	P-value
Age						
7-8 years old	1		1		1	
9-10 years old	0.48 (0.17-1.37)	0.17	0.23 (0.60-0.93)	0.04*	0.25 (0.63-1.02)	0.05*
11-12 years old	0.17 (0.04-0.67)	0.01*	0.16 (0.02-1.12)	0.06	0.29 (0.64-1.30)	0.1
Gender						
Male	1		1		1	
Female	0.72 (0.26-1.96)	0.52	1.64 (0.61-4.40)	0.32	5.29 (1.04-26.88)	0.04*
Health self-perception						
Very good	1				1	
Good	2.21 (0.77-6.38)	0.14	-	-	0.35 (0.07-1.61)	0.18
Fair/poor/very poor	4.69 (1.24-17.65)	0.02*			0.17 (0.03-0.84)	0.03*
Failure						
No	-	-	1		-	-
Yes			7.58 (1.48-38.59)	0.01*		

Caption: [a] Non-verbal sound sequence memory test; [b] Verbal working memory test; [c] Random Gap Detection Test; [d] Odds Ratio; [e] Confidence interval; *p≤0.05

identification, verbal working memory, and non-verbal sequential sound memory[26]. Families with high income and high educational level, including higher education, tend to produce complete sentences, using wider syntax variation, and more complex grammatical structuring, which positively influence the development of the child[9].

In the final model of multivariate analysis, the variables age, gender, health self-perception, and school failure presented statistically significant correlation with the auditory temporal aspects evaluated.

Improved performance was observed in the tests that evaluated temporal processing with advancing age. This finding corroborates the literature, which shows articles reporting improved performance in the NVSSMT and VWMT for children aged four to 14 years[22], as well as in temporal resolution[21]. The processing of information is dependent on the neural function and must be interpreted within the context of neuromaturation. With increasing age, there is a quantitative improvement in the electrophysiological and behavioral tests of auditory processing[27]. Factors such as understanding instructions, motivation, attention to task, learning ability, maturation of the auditory system and auditory memory can justify this improved performance[2,27]. This finding confirms the assumption that the maturational process of the central auditory nervous system occurs gradually, and that the responses to tests that evaluate temporal ordering and resolution are influenced by increasing age.

The results of this study showed that girls were 5.29 times more likely to present altered RGDT results compared with boys. Another study reported that male children presented lower auditory temporal resolution thresholds, that is, better than those of female children, but this finding was not statistically significant[28]. Some studies did not identify the presence of correlation between gender and auditory temporal aspects[20,22,].

The variable school failure presented statistically significant correlation with the simple temporal ordering ability for verbal sounds in sequence. Children with at least one failure record were 7.58 times more likely to present changes in the VWMT. Temporal ordering refers to the ability to perceive, identify, and sort acoustic stimuli according to their order of presentation over a period of time. This ability, in which many perceptual processes are involved, is considered one of the most important functions of the central nervous system, because speech and language comprehension are dependent on it to work with the sound sequence[29]. This finding enhances the hypothesis that there is a relationship between temporal acoustic perception and the perception of speech, and that this difficulty can generate changes in communication, with impact on school achievement.

In this study, children who rated their health as fair, poor, or very poor were 4.69 times more likely to present an altered NVSSMT. It is worth noting that this test assesses simple temporal ordering and that, probably, children who cannot adapt to this ability have a real perception of their academic difficulties, with an impact on health self-perception. Children who reported poorer health perception were also less likely to present an altered RGDT. This finding is not discussed herein, requiring more comprehensive studies so that further conclusions can be reached. We believed that the complexity of the task may have been one of the influences that reduced the number of children who took the RGDT, considering that the study population had deficit in school abilities.

This study was able to identify correlations between auditory temporal aspects and variables related to health self-perception and school and sociodemographic issues. We believe that this study is a breakthrough because, through the statistical model adopted, we were able to analyze a number of independent factors, linked to each other, to predict the occurrence of changes in auditory temporal aspects. However, we reckon that, for a more comprehensive analysis, it would be advisable to conduct further tests to assess the auditory temporal abilities of ordering and resolution. In addition, due to its cross-sectional nature, this study cannot establish causal correlation between the auditory temporal aspects and the factors investigated. It is noteworthy that the inclusion of a comparison group would broaden the study findings.

CONCLUSION

Children with poor school performance showed changes in the auditory temporal aspects. The temporal abilities assessed suggest correlation with different factors such as maturational process, health self-perception, and school profile. The results suggest a need for stimulation of the auditory temporal processing in the therapeutic environment and in the school context, considering the factors associated with poor school performance.

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Author contributions

All of the authors contributed to this study. BAR participated in the collection and analysis of data and writing of the manuscript; AMM and SMAL participated in the study design, data analysis, and critical review of the manuscript.