

Temporal ordering and sound localization: association with environment and language development

Ordenação temporal simples e localização sonora: associação com fatores ambientais e desenvolvimento de linguagem

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ABSTRACT

Purpose: To investigate the simple temporal ordering and sonorous localization of children and the association with family environment resources and language development. **Methods:** Ninety-six children, 42 aged 4 years and 54 aged 5 years and 11 months, were assessed using the Inventory of Resources of the Family Environment, phonological and vocabulary tests, Child Language Test and Simplified Evaluation of Auditory Processing. **Results:** When age was associated to auditory processing skills, it was observed adequacy in both ages, being that male children showed better performance. Individuals who showed poor results in auditory processing skills also showed inadequacy in the areas of Family Environment Resources. Most children who showed adequate auditory processing skills, also showed adequate phonology, but inadequate vocabulary. Children with auditory processing disorders have three times more chance to show changes in vocabulary. **Conclusion:** Most children who had adequate skills in a simple temporal ordering and sound localization also demonstrated adequate phonology.

Keywords: Speech, language and hearing sciences; Auditory perception; Language development; Family relations; Schools

RESUMO

Objetivo: Investigar ordenação temporal simples e localização sonora de crianças, associação com recursos do ambiente familiar e desenvolvimento da linguagem. **Métodos:** Foram avaliadas 96 crianças, sendo 42 com 4 anos e 54 com 5 anos, utilizando-se como instrumentos o Inventário de Recursos do Ambiente Familiar, provas de fonologia e vocabulário do Teste de Linguagem Infantil e Avaliação Simplificada do Processamento Auditivo. **Resultados:** Ao associar idade ao processamento auditivo e suas habilidades, observou-se adequação em ambas as idades, sendo que crianças do gênero masculino apresentaram melhor desempenho. Os indivíduos com resultados inadequados nas habilidades do processamento auditivo apresentaram, também, inadequação nos domínios do Recurso do Ambiente Familiar. Na maior parte das crianças que apresentaram as habilidades de processamento auditivo adequadas, a fonologia também estava adequada, mas o vocabulário era inadequado. Crianças com processamento auditivo alterado tem três vezes mais chances de apresentarem alteração no vocabulário. **Conclusão:** A maior parte das crianças que apresentou adequação das habilidades de ordenação temporal simples e localização sonora demonstrou também fonologia adequada.

Descritores: Fonoaudiologia; Percepção auditiva; Desenvolvimento da linguagem; Relações familiares; Instituições acadêmicas

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INTRODUCTION

Auditory processing is the ability of the Central Nervous System to efficiently and effectively use auditory information⁽¹⁾ and covers skills to locate the sound source, focus, understand, discriminate and recognize sound stimuli⁽²⁾. The reception, analysis and interpretation of sounds depend on this skill set and not just on normal hearing⁽³⁾. The proper functioning of the central and peripheral auditory structures is necessary, otherwise, difficulties will be detected in the receipt, analysis and organization of auditory information⁽¹⁾.

The auditory experiences play an important role in the ability of human communication and understanding, socialization and learning processes. In addition, other cognitive functions, such as attention, perception and memory, even if not directly integrated with auditory processing, have great influence on it, as well as language development⁽⁴⁾ and family environment⁽⁵⁾. Regarding language development, two of its levels are related to auditory processing: phonology – acquisition of phonemes⁽⁶⁾ – and vocabulary – acquisition of semantic system⁽⁷⁾. The importance of the family environment consists in the exposition of the children to auditory experiences that influence their development⁽⁵⁾.

The development of language involves complex processes, with neural networks that connect different brain regions related to speech perception. This ability closely depends of the integrity of the peripheral and central auditory pathways⁽⁸⁾. Language disorders may be related to low performance in auditory processing skills, as it can interfere with the discrimination of speech sounds. Thus, less stable neural representations would be constructed, affecting speech perception and production⁽⁹⁾.

The interaction between biological and environmental factors is necessary for the full development of the children. Social, emotional and sensory stimulation will influence the cognitive development that occurs during the development of language and maturation of the auditory pathways. If these environmental stimuli do not occur effectively, the child is subject to disorders of auditory processing and language⁽¹⁰⁾.

The auditory processing can be divided into the following skills: location and lateralization of the sound; auditory discrimination; recognition of auditory pattern; temporal aspects of hearing, including the temporal ordering; auditory performance under competing acoustic signals (including dichotic listening) and auditory performance with degradation of acoustic signals⁽¹¹⁾.

This article highlights the simple, verbal and non-verbal temporal ordering, and the sound localization. The temporal ordering is related to the processing of various auditory stimuli, according to their order of occurrence. Thus, the individual can discriminate the correct sequence of sounds that can be: from speech (verbal), or from nature (non-verbal)⁽¹²⁾. The sound location is used to determine the position of a sound source in the space and, for that, the individual uses monaural

and binaural cues. It is realized through the structures of the Central Nervous System pathways, especially at the level of the brainstem and auditory cortex. As both ears receive the sound simultaneously, the first stimulated one indicates the direction of the sound source⁽¹³⁾.

In this work, the emphasis on auditory processing in the age between 4 and 5 years and 11 months old is intended to highlight its association with the development of language and family environment, and the importance of the diagnosis of changes in this capacity of the Central Nervous System and consequent intervention. The neuronal plasticity is more active to hearing training in the ages surveyed, i.e., at this point the stimulus should be given in order to minimize deviations and avoid future impairment⁽⁵⁾.

Therefore, the purpose of this study was to investigate simple temporal ordering and sound localization of children aged between 4 years and 5 years and 11 months, students of early childhood education units, and the association with the family environment resources and language development.

METHODS

This is an observational analytic cross-sectional study with non-probability sample conducted with 96 children, 42 aged 4 years and 54 aged 5 years and 11 months. The study was approved by the Research Ethics Committee of the *Universidade Federal de Minas Gerais* (UFMG), under the opinion ETIC 288/10, and all those responsible signed the Free and Cleared Term of Consent.

The criteria for inclusion of children in this study were: to have the proposed age and signature of the Free and Cleared Term of Consent by those responsible. Children whose guardians answered less than 70% of the questionnaire Resources of the Family Environment (RAF)⁽¹⁴⁾, who did not go to the educational institution, who did not have cochleopalpebral reflex or evidence of neurogenic or cognitive changes, who were under evaluation or speech therapy, or who had a previous diagnosis of hearing impairment were excluded.

The scenario of the study was composed of three child education institutions in the northeast region of the city of Belo Horizonte, Minas Gerais, being two of public funding and one of private funding. The evaluation of the children was held in a room provided by the management of each child education institution, in two individual sessions of approximately 40 minutes in different days.

Initially, the parents answered the RAF questionnaire, which considers the routine of the children and their family environment –, through ten topics, with open questions and multiple choice items. Each topic consisted of open questions with items to be selected by the interviewee and, if the answers were not in the list, the item “other” was selected. To calculate the raw score, the items selected in each topic were added except those with specific scores (8, 9 and 10). In the relative score, it is

suggested to use the formula *raw score/maximum score of the topic x 10*, where the maximum score is the number of items. Thus, the recommendations of the RAF author⁽¹⁴⁾ were used for the analysis of the instrument.

The phonology test of ABFW⁽¹⁵⁾, used for the assessment of phonological skills of the subjects, was applied and tested in accordance with the recommendations of the authors of this paper.

The vocabulary test of ABFW⁽¹⁶⁾ was used in the lexical evaluation, which consists in the appointment, by the child, of 118 figures distributed in nine conceptual fields (clothing, animals, food, transportation, furniture and fixtures, professions, places, shapes and colors, toys and musical instruments). The responses were recorded, transcribed in the protocol of records and performed in different days of the phonology test in order to eliminate the influence of fatigue. The reference criteria of the instrument were used for the test analysis.

The auditory processing was assessed by tasks of simple temporal ordering and sound localization. The tests used were: memory test of verbal sounds in sequence, memory test of non-verbal sounds in sequence and sound localization test in five directions⁽¹⁷⁾.

The verbal sound sequencing test was applied using three syllables (pa, ta, ka). Initially, the individuals should repeat each syllable independently. Then they were instructed to verbally repeat three different sequences, composed of three syllables each, keeping the exact order of presentation, without visual cues. Three musical instruments (rattle, coconut and bell) were used for the non-verbal sound sequencing test, presented in three different sequences. The children were asked to point to musical instruments in the order in which they were played. The sound localization test was performed by issuing the percussion of a bell in the five plans of the head: right, left, up, back and forth. The students were instructed by demonstration, to point to the direction of the sound, with no visual cues⁽¹⁷⁾.

The data were stored in electronic format and consolidated into a database in Excel®. The descriptive results were obtained by frequencies and percentages for the characteristics of the various categorical variables and attainment of measures of central tendency (mean) and measure of dispersion (standard deviation) for quantitative variables. To verify the relationship between the variables, the Mann-Whitney test, Fisher's Exact test and Pearson Chi-Square test were used. The magnitude of this association was calculated using the odds ratio with 95% confidence intervals. For comparisons whose p-value was less than 0.05, it was considered association with statistical significance. For processing and data analysis, the SPSS statistical software version 18.0 was used.

RESULTS

In this study, the sample consisted mostly of male children aged 5 years. With regard to the types of research institutions,

most students (59.4%) were from public institutions (schools A and B). It is important to highlight that, regarding the parental education, the majority has completed high school followed by those who reported to have completed higher education and, finally, primary education (Figure 1).

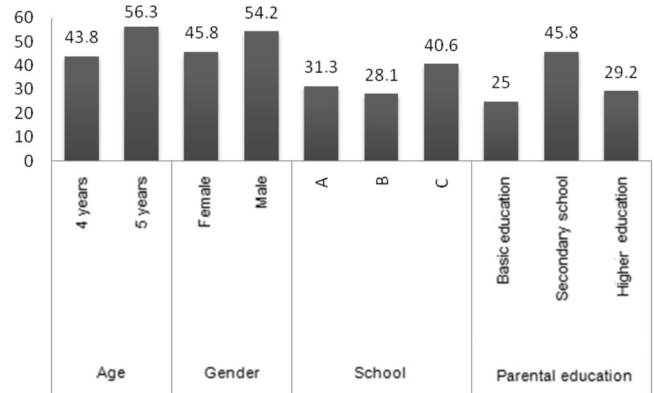


Figure 1. Characterization of the sample in terms of age, gender, educational institution and parental education

When age was associated to auditory processing skills, it was observed that, in all of them, most of the children got adequate results according to the criteria proposed in the literature⁽¹⁷⁾, in the sound localization of four to five hits, two hits in sequence of three sounds in three attempts in the nonverbal sequential memory and two to three hits in the verbal sequential memory (Table 1).

When auditory processing was associated to gender, it was observed that the male children showed more adequate results. Regarding the skills of nonverbal sequential memory, verbal sequential memory and location memory, the male subjects showed better results when compared to females. There was not a result with statistical significance between the evaluated skills and gender (Table 2).

The relationship between auditory processing, parental education and type of educational institution showed a statistical significance in the private funding institution and most of the children with parents with higher education showed adequate auditory processing. In public funding institutions, the adequacy of children with parents with high school was higher.

In general, most children with adequate auditory processing had parents with higher education, a significant result (Table 3).

Of the 96 children evaluated, those who had inadequate results in the skills of auditory processing also showed inadequacy in the RAF areas. It is noteworthy that the sound localization test, compared to verbal and non-verbal sequential memory tests revealed more children with inadequate results. The results of the study showed that family environment is related with the hearing process, a fact that showed statistical significance. This relationship reflects the interaction between the domain "Family Connection" of the RAF and the verbal and non-verbal sequential memory skills and sound localization memory (Table 4).

Table 1. Relationship between auditory processing skills and age

	Age				p-value
	4 years		5 years		
	n	%	n	%	
Auditory processing					
Inadequate	21	50	22	40.7	0.412
Adequate	21	50	32	59.3	
Non-verbal sequential memory					
Inadequate	9	21.4	9	16.7	0.605
Adequate	33	78.6	45	83.3	
Verbal sequential memory					
Inadequate	4	9.5	3	5.6	0.695
Adequate	38	90.5	51	94.4	
Sound localization					
Inadequate	19	45.2	18	33.3	0.292
Adequate	23	54.8	36	66.7	

Fisher's Exact Test ($p \leq 0.05$)**Table 2.** Relationship between auditory processing skills and gender

	Gender				p-value
	Male		Female		
	n	%	n	%	
Auditory processing					
Inadequate	23	44.2	20	45.5	1
Adequate	29	55.8	24	54.5	
Non-verbal sequential memory					
Inadequate	7	13.5	11	25	0.192
Adequate	45	86.5	33	75	
Verbal sequential memory					
Inadequate	3	5.8	4	9.1	0.699
Adequate	49	94.2	40	90.9	
Sound localization					
Inadequate	21	40.4	16	36.4	0.834
Adequate	31	59.6	28	63.6	

Fisher's Exact Test ($p \leq 0.05$)

When auditory processing, phonology and vocabulary area were associated, it was observed that, most children with appropriate auditory processing skills also showed adequate phonology. There was a statistically significant association between auditory processing disorders and change in vocabulary.

The data analysis revealed that, in the present study, children with auditory processing disorders had 3.10 times more chance to show changes in the vocabulary when compared to children without auditory processing disorders (Table 5).

DISCUSSION

This study was based on non-probabilistic sample, in which

the participants were mostly students from public institutions and most of the parents completed high school, which did not confirm the Census 2010⁽¹⁸⁾. This shows that there was a reduction in the percentage of people without education or with incomplete primary education, which still represent the majority. It should be borne in mind that the Census is a nationwide survey, and, in the municipality of collection, such data was not found.

The relationship between age and performance of the children in the auditory processing showed that children aged 5 years showed more adequacy, result justified by the fact that the hearing abilities improve over time, associated with the time of exposition to sound stimulus^(19,20).

In this study, the comparison between gender and auditory

Table 3. Relationship between auditory processing, parental education and educational institution

Auditory processing		Parental education						p-value
		Basic education		Secondary school		Higher education		
		n	%	n	%	n	%	
Institution A	Inadequate	7	100	10	58.8	4	66.7	0.132
	Adequate	0	0	7	41.2	2	33.3	
Institution B	Inadequate	10	62.5	6	60	1	100	0.731
	Adequate	6	37.5	4	40	0	0	
Institution C	Inadequate	1	100	3	17.6	1	4.8	0.015*
	Adequate	0	0	14	82.4	20	95.2	
Total	Inadequate	18	75	19	43.2	6	21.4	<0.001*
	Adequate	6	25	25	56.8	22	78.6	

* Significant values ($p \leq 0.05$) – Pearson Chi-square Test**Table 4.** Relationship between auditory processing and resources of the family environment

RAF	Verbal sequential memory			Non-verbal sequential memory			Sound localization			Total auditory processing			
	I	A	p-value	I	A	p-value	I	A	p-value	I	A	p-value	
Family connection	n	7	89	18	78		37	59		43	53		
	Min	10.1	14.9	13.7	10.1		14.9	10.1		10.1	14.9		
	Max	34.5	62.4	49.4	62.4		49.4	62.4		49.4	62.4		
	M	20.7	32.3	0.026*	25.6	32.8	0.001*	26.3	34.7	0.001*	25.9	35.9	<0.001*
	SD	8.8	11.7		9.9	11.9		9.1	12.2		9.7	11.5	
	Med	18.7	32.3		25.4	35		25.4	37		25.4	37.7	
School-family connection	n	7	89	18	78		37	59		43	53		
	Min	13	11	13	11		11	12		11	12		
	Max	24	29	24	29		26	29		26	29		
	M	18.7	20.1	0.824	19.8	20.1	0.415	20.5	19.7	0.288	20.2	19.9	0.633
	SD	4.8	4		4	4.1		4.1	4.1		4.3	3.9	
	Med	19	19		21	19		21	19		20	19	
Family life stability	n	7	89	18	78		37	59		43	53		
	Min	1	2	2	1		2	1		1	3		
	Max	12	16	14	16		15	16		15	16		
	M	7.4	8.8	0.231	7.6	9	0.382	8.3	9	0.603	8	9.3	0.184
	SD	4.2	4		4	4		4.2	3.8		4.2	3.7	
	Med	8	9		8.5	9		9	9		9	9	
Total	n	7	89	18	78		37	59		43	53		
	Min	24.1	34.9	34.9	24.1		34.9	24.1		24.1	37.7		
	Max	61.5	107.4	80.4	107.4		84.6	107.4		84.6	107.4		
	M	46.9	61.3	0.019*	53	61.9	0.013*	55.1	63.4	0.007*	54.1	65.2	<0.001*
	SD	11.3	14.5		11.8	14.8		12.7	15.1		13.3	14	
	Med	49.7	60		50.4	61.9		50.4	64.9		50.4	65.3	

* Significant values ($p \leq 0.05$) – Mann-Whitney Test**Note:** SD = standard deviation; Min = minimum; Max = maximum; Med = median; I = inadequate; A = appropriate

processing revealed no statistical significance. However, the boys showed the greatest number of results according to the reference standards for abnormality. This fact showed variation in the researched literature, as studies have suggested that

the maturation process of the central auditory system of both genders^(21,22) is similar. There is still prevalence of hearing impairment in males⁽²³⁾, a finding that does not agree with the result obtained in that article.

Table 5. Relationship between auditory processing, vocabulary and phonology, considering the odds ratio

	Auditory processing				p-value	OR	CI 95%
	Inadequate		Adequate				
	n	%	n	%			
Vocabulary							
Inadequate	35	81.4	31	58.5	0.026	3.10	1.11 – 8.91
Adequate	8	18.6	22	41.5			
Phonology							
Inadequate	1	2.3	6	11.3	0.126	0.19	0.01 – 1.68
Adequate	42	97.7	47	88.7			

* Significant values ($p \leq 0.05$) – Fisher's Exact Test

Note: OR = odds ratio; CI = confidence interval

When auditory processing, parental education and type of educational institution were associated, a greater number of children with adequacy was found in private institutions (Figure 1). This result confirms the researched literature⁽²⁴⁾, which states that the lack of teaching resources and professionals available by public educational institutions can contribute to the delay in cognitive development of students, compared to those belonging to private institutions. Among the children of private institutions, those with parents with higher education had better results, since those of the public institutions which showed more adequacy had parents with high school. The higher level of parental education can influence the quantity and quality of linguistic and auditory stimuli provided and allows for greater listening experience of the children. The relationship established between the adequacy of hearing abilities and the type of institution is unprecedented in the literature. However, according to the researched literature⁽²⁵⁾, the education of the mothers is critical for the cognitive development of the children, since it determines factors such as environmental organization, cognitive stimulation and variation of daily stimulus.

In the analysis of the relationship between auditory processing and resources of the family environment, it was observed that children with abnormal results in auditory processing skills have also showed inadequacy in RAF areas. This test evaluates the stimuli provided in the family environment and, when they are limited, there is a loss in the development of listening skills. In the present study, the children did not show good results in the RAF, which may be related to socioeconomic variables of the families surveyed. This finding is confirmed by the literature, which states that the acoustic experience provided by the family environment has a direct influence on the child's auditory behavior⁽²⁶⁾.

The influence of the family environment in auditory processing skills validated the findings in the literature, by showing that the plasticity of the central nervous system is closely related to resources to which they are exposed^(5,26).

The largest number of errors found in the sound localization test is related to the demand for greater maturation of auditory skills, which can be difficult due to the age of the children.

According to the literature⁽²⁷⁾, hearing tests depend on neural function and therefore consider the neural maturation process, which is closely related to the age of the children. On the other side, the largest amount of hits of the verbal sequential memory test occurs by the constant exposure of the children to the spoken language, independent of any other variable mentioned in the study.

In the analysis of the relationship between auditory processing, phonology and vocabulary, it was found that children with appropriate auditory processing skills also showed adequacy in phonology, a fact that was not observed in the vocabulary. A possible explanation is the chronic nature of the development. The literature shows that, in language development, the phonological inventory is acquired prior to the expansion of vocabulary⁽²⁸⁾.

In the analysis of the relationship between performance in the auditory processing tests and vocabulary, the results showed that children with auditory processing disorder have higher chances to also present inappropriate vocabulary, compared to those without auditory processing disorders. This happens because language difficulties, such as phonological and lexical inventory disorders are closely related to auditory processing disorders, since hearing is an important entry point for language acquisition⁽²⁹⁾.

According to the findings, the discussion of the relationship between phonological and lexical development, the auditory processing and the family environment of the children show to be relevant, as this theme can add advances to the area of speech therapy and health promotion. The importance of the parental education and of the resources of the family and school environment is highlighted since they determine not only the language development as also the overall development of the child. It should be also emphasized, that the association between auditory processing tests, phonology and vocabulary used are extremely important instruments in the clinical assessment of the child development.

Advances were provided by the present study, however, some limitations were detected. The size and design of the sample can be mentioned, since only two public educational institutions and one private institution were used, fact that

prevents the generalization of the findings. Another limitation was the lack of evaluation of peripheral hearing, which limits the discussion of the findings. In addition, activities involving the teaching methodology of the institutions were not conducted during the study. Therefore, it becomes necessary to conduct future research with population studies, in order to obtain more consistent results to be incorporated into professional practice.

CONCLUSION

The association between auditory processing and language development in the age from 4 years to 5 years and 11 months revealed that most of the children that showed adequacy of the skills of simple temporal ordering and sound localization also demonstrated adequate phonology.

The data revealed that children with auditory processing disorders were more likely to show change in vocabulary compared to children without auditory processing disorders.

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