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Temporal ordering and reading competence of words and pseudowords: a preliminary study

Ordenação temporal e competência leitora de palavras e pseudopalavras: estudo preliminar

ABSTRACT

Purpose: Analyze the association of simple and complex auditory temporal ordering skills with reading competence tasks in students. **Methods:** Pilot phase of a cross-sectional study conducted with a non-probabilistic sample of 22 schoolchildren aged eight to ten years. Instruments for evaluation of reading competence tasks and simple and complex auditory temporal ordering abilities were used. **Results:** Most participants obtained adequate results in the tests of simple auditory temporal ordering (SATO) and reading competence (RC), but inadequate results in the test of complex auditory temporal ordering (CATO). The association of reading competence with temporal processing showed no statistical significance. **Conclusion:** The study evidenced the importance to conduct more robust studies on the theme and the viability of data collection in the school scenario.

RESUMO

Objetivo: Analisar a associação entre habilidades de ordenação temporal simples e complexas e tarefas de competência leitora em escolares. **Método:** Etapa piloto de estudo transversal com amostra não probabilística, realizada com 22 escolares, na faixa etária de oito a dez anos. Foram utilizados os instrumentos de avaliação da competência leitora e de avaliação das habilidades auditivas de ordenação temporal simples e complexa. **Resultados:** As habilidades auditivas de ordenação temporal simples, assim como os resultados do teste de competência leitora, apresentaram resultado normal na maioria dos participantes. As habilidades de ordenação temporal complexa, por sua vez, apresentaram resultado inadequado na maioria dos escolares. A associação da competência leitora com o processamento temporal não demonstrou significância estatística. **Conclusão:** O estudo demonstrou a importância da realização de estudos mais robustos e a viabilidade de coleta de dados no cenário escolar.

Study carried out at the Departamento de Fonoaudiologia, Curso de Fonoaudiologia, Faculdade de Medicina, Universidade Federal de Minas Gerais – UFMG - Belo Horizonte (MG), Brazil.

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INTRODUCTION

Central auditory processing involves a set of skills that allows the listener to interpret the message heard⁽¹⁾. Therefore, disorders in this processing are commonly associated with learning difficulties and language impairments^(1,2). Considering that reading is an important tool for acquiring new knowledge, the association of reading competence (RC) with auditory skills is justified, because both are essential for learning⁽³⁻⁵⁾.

Temporal auditory processing is related to the ability to recognize, identify, and order acoustic stimuli during a given time, according to the order in which they were presented⁽⁶⁾. Based on the fact that this auditory ability is essential for speech and language comprehension, its inadequacy may reflect difficulties in spelling and coding/decoding both words and phrases⁽⁶⁻⁹⁾.

It is worth emphasizing that investigating the interrelationship between RC and temporal processing is crucial, and it can produce intervention proposals for the school population. Therefore, the objective of this study was to analyze the association of simple and complex auditory temporal ordering skills with reading competence tasks in schoolchildren.

METHODS

This is the pilot phase of a cross-sectional study conducted with a non-probabilistic sample of 22 schoolchildren aged eight to ten years in a public municipal school located in Belo Horizonte, Minas Gerais state, Brazil. The survey was approved by the Research Ethics Committee of the Universidade Federal de Minas Gerais under protocol no. CAAE 0672.0.203.000-11. The parents and/or legal guardians of the participants signed an Informed Consent Form prior to study commencement.

Inclusion criteria comprised schoolchildren with no evidence or history of cognitive, neurological, neuropsychiatric or motor impairments. Students who were illiterate, undergoing speech-language therapy or assessment, and presented “fail” results in the Transient-evoked Otoacoustic Emission (TEOAE) examination were excluded from the sample.

Data collection was performed in a space provided by the school, in a single session of approximately 40 min. The following procedures were conducted:

- Hearing assessment: Meatoscopy and TEOAE (Bio-logic AuDX[®]) and, in case of a “fail” result, Tympanometry (Titan, Interacoustics) was conducted.
- Word-pseudoword Reading Competence (WPRC) test⁽¹⁰⁾: assesses the silent reading of words and pseudowords, and it is composed of seven subtests. For analysis, the students who obtained “very low” and “low” scores, both in the overall test result and in each of its subtests, were considered to present altered performance, whereas those who received “medium” and “high” scores were regarded as presenting normal performance.

- Assessment of simple auditory temporal ordering (SATO)⁽¹¹⁾: individual application of the tests of Sequential Memory of Verbal/Non-verbal Sounds
- Assessment of complex auditory temporal ordering (CATO): application of frequency and duration tests, Frequency Pattern Test (FPT) and Duration Pattern Test (DPT), respectively⁽¹²⁾, to groups of three or four schoolchildren positioned at the same distance from the loudspeaker. The tests were conducted in dichotic listening with presentation of sequences of three and four sounds⁽¹²⁾.

The Fisher’s exact test was used for correlation analysis, and associations presenting values of $p \leq 0.05$ were considered statistically significant. The SPSS, 20.0 software was used to process the data.

RESULTS

The study sample was composed of 22 schoolchildren, mostly female (63.6%), aged eight years to ten years, 11 months and 29 days. Regarding schooling, the sample was distributed from 1st to 4th grades of Elementary School.

Analysis of simple auditory temporal ordering (SATO) skills for Sequential Memory of Verbal (SMVS) and Non-verbal (SMNVS) Sounds revealed that 68.2% of the participants presented adequate results in the tests. The Frequency Pattern Test (FPT) showed adequate results for 3.6% and 17.9% of the participants for sequences of three and four sounds, respectively; whereas the Duration Pattern Test (DPT) presented adequate results for 5.4% and 19.6% of the participants for sequences of three and four sounds, respectively.

Descriptive analysis of the Word-pseudoword Reading Competence (WPRC) test verified that 95.5% of the participants obtained normal results⁽¹⁰⁾. Similar results were verified in the subtests of rejection of strange pseudowords and rejection of visual neighbor pseudowords. All participants presented normal results in the subtests of rejection of semantic neighbor words, acceptance of regular correct words, and acceptance of irregular correct words. In the subtests of rejection of phonological neighbor pseudowords and rejection of pseudo homophones, 72.7% and 90.9% of the schoolchildren, respectively, presented normal results.

Despite the absence of statistical significance, it was possible to observe that most students with normal results in the WPRC test also presented adequate performance in SATO skills (Table 1).

Association of the WPRC test and its subtests with the frequency and duration tests also presented statistical significance, but evidenced that most participants with normal results in the reading competence (RC) tasks showed inadequate performance in complex auditory temporal ordering (CATO) skills. In addition, the schoolchildren presented poorer performance in the tasks involving frequency and duration patterns with three-sound sequences (FPT-3 and DPT-3, respectively) compared with that in the tasks involving frequency and duration patterns with four-sound sequences (FPT-4 and DPT-4, respectively) (Table 2).

Table 1. Correlation between the results for the tests of simple auditory temporal ordering (SATO) and reading competence (RC)

WPRC	Simple auditory temporal ordering			Simple auditory temporal ordering		
	SMVS		p-value	SMNVS		p-value
	Adequate N (%)	Inadequate N (%)		Adequate N (%)	Inadequate N (%)	
SP						
Altered	1 (4.5%)	0 (0.0%)	1	1 (4.5%)	0 (0.0%)	1
Normal	14 (63.7%)	7 (31.8%)		14 (63.7%)	7 (31.8%)	
Total	15 (68.2%)	7 (31.8%)		15 (68.2%)	7 (31.8%)	
SNW						
Altered	0 (0.0%)	0 (0.0%)	*	0 (0.0%)	0 (0.0%)	*
Normal	15 (68.2%)	7 (31.8%)		15 (68.2%)	7 (31.8%)	
Total	15 (68.2%)	7 (31.8%)		15 (68.2%)	7 (31.8%)	
CRW						
Altered	0 (0.0%)	0 (0.0%)	*	0 (0.0%)	0 (0.0%)	*
Normal	15 (68.2%)	7 (31.8%)		15 (68.2%)	7 (31.8%)	
Total	15 (68.2%)	7 (31.8%)		15 (68.2%)	7 (31.8%)	
VNP						
Altered	1 (4.5%)	0 (0.0%)	1	0 (0.0%)	1 (4.5%)	0.32
Normal	14 (63.7%)	7 (31.8%)		15 (68.2%)	6 (27.3%)	
Total	15 (68.2%)	7 (31.8%)		15 (68.2%)	7 (31.8%)	
CIW						
Altered	0 (0.0%)	0 (0.0%)	*	0 (0.0%)	0 (0.0%)	*
Normal	15 (68.2%)	7 (31.8%)		15 (68.2%)	7 (31.8%)	
Total	15 (68.2%)	7 (31.8%)		15 (68.2%)	7 (31.8%)	
PNW						
Altered	3 (13.6%)	3 (13.6%)	0.33	4 (18.2%)	2 (9.1%)	1
Normal	12 (54.6%)	4 (18.2%)		11 (50.0%)	5 (22.7%)	
Total	15 (68.2%)	7 (31.8%)		15 (68.2%)	7 (31.8%)	
PH						
Altered	1 (4.5%)	1 (4.5%)	1	1 (4.5%)	1 (4.5%)	1
Normal	14 (63.7%)	6 (27.3%)		14 (63.7%)	6 (27.3%)	
Total	15 (68.2%)	7 (31.8%)		15 (68.2%)	7 (31.8%)	
TOTAL						
Altered	1 (4.5%)	0 (0.0%)	1	0 (0.0%)	1 (4.5%)	0.31
Normal	14 (63.7%)	7 (31.8%)		15 (68.2%)	6 (27.3%)	
Total	15 (68.2%)	7 (31.8%)		15 (68.2%)	7 (31.8%)	

*It was not possible to perform correlation analysis because all the students presented normal results according to the reference criteria for age group and schooling¹⁰; Fisher's exact test

Captions: N = number of schoolchildren; SMNVS = Test of Sequential Memory of Non-verbal Sounds; SMVS = Test of Sequential Memory of Verbal Sounds; WPRC = Test of Word-pseudoword Reading Competence; SP = Subtest of rejection of strange pseudowords; SNW = Subtest of rejection of semantic neighbor words; CRW = Subtest of acceptance of regular correct words; VNP = Subtest of rejection of visual neighbor pseudowords; CIW = Subtest of acceptance of irregular correct words; PNW = Subtest of rejection of phonological neighbor pseudowords; PH = Subtest of rejection of pseudo homophones

Table 2. Correlation between the results for the tests of complex auditory temporal ordering (CATO) and reading competence (RC)

WPRC	Complex auditory temporal ordering					Complex auditory temporal ordering						
	FPT-3		p-value	FPT-4		p-value	DPT-3		p-value	DPT-4		p-value
	Adequate N (%)	Inadequate N (%)		Adequate N (%)	Inadequate N (%)		Adequate N (%)	Inadequate N (%)		Adequate N (%)	Inadequate N (%)	
SP												
Altered	0 (0.0%)	1 (4.8%)	1.00	0 (0.0%)	1 (4.8%)	0.47	0 (0.0%)	1 (4.8%)	1.00	1 (4.8%)	0 (0.0%)	0.43
Normal	2 (9.5%)	18 (85.7%)		7 (33.3%)	13 (61.9%)		3 (14.3%)	17 (80.9%)		8 (38.0%)	12 (57.2%)	
Total	2 (9.5%)	19 (90.5%)		7 (33.3%)	14 (66.7%)		3 (14.3%)	18 (85.7%)		9 (42.8%)	12 (57.2%)	

*It was not possible to perform correlation analysis because all the students presented normal results according to the reference criteria for age group and schooling¹⁰; Fisher's exact test

Captions: N = number of schoolchildren; FPT = Frequency Pattern Test; FPT-3 = Frequency Pattern Test with three-sound sequence; FPT-4 = Frequency Pattern Test with four-sound sequence; DPT = Duration Pattern Test; DPT-3 = Duration Pattern Test with three-sound sequence; DPT-4 = Duration Pattern Test with four-sound sequence; WPRC = Test of Word-pseudoword Reading Competence; SP = Subtest of rejection of strange pseudowords; SNW = Subtest of rejection of semantic neighbor words; CRW = Subtest of acceptance of regular correct words; VNP = Subtest of rejection of visual neighbor pseudowords; CIW = Subtest of acceptance of irregular correct words; PNW = Subtest of rejection of phonological neighbor pseudowords; PH = Subtest of rejection of pseudo homophones

Table 2. Continued...

WPRC	Complex auditory temporal ordering						Complex auditory temporal ordering					
	FPT-3		p-value	FPT-4		p-value	DPT-3		p-value	DPT-4		p-value
	Adequate N (%)	Inadequate N (%)		Adequate N (%)	Inadequate N (%)		Adequate N (%)	Inadequate N (%)		Adequate N (%)	Inadequate N (%)	
SNW												
Altered	0 (0.0%)	0 (0.0%)	*	0 (0.0%)	0 (0.0%)	*	0 (0.0%)	0 (0.0%)	*	0 (0.0%)	0 (0.0%)	*
Normal	2 (9.5%)	19 (90.5%)		7 (33.3%)	14 (66.7%)		3 (14.3%)	18 (85.7%)		9 (42.8%)	12 (57.2%)	
Total	2 (9.5%)	19 (90.5%)		7 (33.3%)	14 (66.7%)		3 (14.3%)	18 (85.7%)		9 (42.8%)	12 (57.2%)	
CRW												
Altered	0 (0.0%)	0 (0.0%)	*	0 (0.0%)	0 (0.0%)	*	0 (0.0%)	0 (0.0%)	*	0 (0.0%)	0 (0.0%)	*
Normal	2 (9.5%)	19 (90.5%)		7 (33.3%)	14 (66.7%)		3 (14.3%)	18 (85.7%)		9 (42.8%)	12 (57.2%)	
Total	2 (9.5%)	19 (90.5%)		7 (33.3%)	14 (66.7%)		3 (14.3%)	18 (85.7%)		9 (42.8%)	12 (57.2%)	
VNP												
Altered	0 (0.0%)	1 (4.8%)	0.74	0 (0.0%)	1 (4.8%)	1.00	0 (0.0%)	1 (4.8%)	1.00	0 (0.0%)	1 (4.8%)	0.38
Normal	2 (9.5%)	18 (85.7%)		7 (33.3%)	13 (61.9%)		3 (14.3%)	17 (80.9%)		9 (42.8%)	11 (52.4%)	
Total	2 (9.5%)	19 (90.5%)		7 (33.3%)	14 (66.7%)		3 (14.3%)	18 (85.7%)		9 (42.8%)	12 (57.2%)	
CIW												
Altered	0 (0.0%)	0 (0.0%)	*	0 (0.0%)	0 (0.0%)	*	0 (0.0%)	0 (0.0%)	*	0 (0.0%)	0 (0.0%)	*
Normal	2 (9.5%)	19 (90.5%)		7 (33.3%)	14 (66.7%)		3 (14.3%)	18 (85.7%)		9 (42.8%)	12 (57.2%)	
Total	2 (9.5%)	19 (90.5%)		7 (33.3%)	14 (66.7%)		3 (14.3%)	18 (85.7%)		9 (42.8%)	12 (57.2%)	
PNW												
Altered	0 (0.0%)	6 (28.6%)	0.91	2 (9.5%)	4 (19.0%)	1.00	1 (4.8%)	5 (23.8%)	0.84	2 (9.5%)	4 (19.1%)	0.66
Normal	2 (9.5%)	13 (61.9%)		5 (23.8%)	10 (47.7%)		2 (9.5%)	13 (61.9%)		7 (33.3%)	8 (38.1%)	
Total	2 (9.5%)	19 (90.5%)		7 (33.3%)	14 (66.7%)		3 (14.3%)	18 (85.7%)		9 (42.8%)	12 (57.2%)	
PH												
Altered	0 (0.0%)	2 (9.5%)	1.00	1 (4.8%)	1 (4.8%)	1.00	0 (0.0%)	2 (9.5%)	0.55	0 (0.0%)	2 (9.5%)	0.49
Normal	2 (9.5%)	17 (81.0%)		6 (28.5%)	13 (61.9%)		3 (14.3%)	16 (76.2%)		9 (42.8%)	10 (47.7%)	
Total	2 (9.5%)	19 (90.5%)		7 (33.3%)	14 (66.7%)		3 (14.3%)	18 (85.7%)		9 (42.8%)	12 (57.2%)	
TOTAL												
Altered	0 (0.0%)	1 (4.8%)	0.74	0 (0.0%)	1 (4.8%)	1.00	0 (0.0%)	1 (4.8%)	0.67	0 (0.0%)	1 (4.8%)	1.00
Normal	2 (9.5%)	18 (85.7%)		7 (33.3%)	13 (61.9%)		3 (14.3%)	17 (80.9%)		9 (42.8%)	11 (52.4%)	
Total	2 (9.5%)	19 (90.5%)		7 (33.3%)	14 (66.7%)		3 (14.3%)	18 (85.7%)		9 (42.8%)	12 (57.2%)	

*It was not possible to perform correlation analysis because all the students presented normal results according to the reference criteria for age group and schooling⁽¹⁰⁾; Fisher's exact test

Captions: N = number of schoolchildren; FPT = Frequency Pattern Test; FPT-3 = Frequency Pattern Test with three-sound sequence; FPT-4 = Frequency Pattern Test with four-sound sequence; DPT = Duration Pattern Test; DPT-3 = Duration Pattern Test with three-sound sequence; DPT-4 = Duration Pattern Test with four-sound sequence; WPRC = Test of Word-pseudoword Reading Competence; SP = Subtest of rejection of strange pseudowords; SNW = Subtest of rejection of semantic neighbor words; CRW = Subtest of acceptance of regular correct words; VNP = Subtest of rejection of visual neighbor pseudowords; CIW = Subtest of acceptance of irregular correct words; PNW = Subtest of rejection of phonological neighbor pseudowords; PH = Subtest of rejection of pseudo homophones

DISCUSSION

Two thirds of the schoolchildren investigated presented adequate results in simple auditory temporal ordering (SATO) skills. This finding differs from data reported by other authors⁽⁶⁾, who demonstrated a higher percentage of students with inadequacy in such skills. It is worth considering the difference between the studies, because whereas the present research was conducted with children with typical development, the compared study also conducted in Minas Gerais state worked with students with poor school performance. However, the percentage of inadequate results (one-third) of the present study is quite significant, because auditory skills are fundamental for the literacy process.

Correlation between the Word-pseudoword Reading Competence (WPRC) test and SATO skills showed that most

of the schoolchildren analyzed presented normal and adequate results, respectively, in both assessments. Despite the absence of statistical significance, this finding corroborates the literature⁽¹³⁾, because impairments in auditory processing are often associated with difficulties in reading, writing, and learning^(2,9,13-15). To this extent, the present data reinforce the importance of the hearing-language interaction.

Association of performance in reading competence (RC) with complex auditory temporal ordering (CATO) skills showed that most of the schoolchildren that obtained normal scores in the WPRC tests also presented inadequate results in the tests of Frequency and Duration Patterns. Nevertheless, these data differ from those found in other studies, which reported recurrent presence of auditory processing disorders, especially temporal processing, in students with language disorders, mainly of

reading and learning^(1-2,9,15). Moreover, the students presented higher score percentages in duration pattern tests with three and four sound sequences compared with those in the frequency pattern tests, corroborating the national literature⁽¹²⁾. It should be emphasized that the duration and frequency patterns are essential in understanding and using language. However, it is worth noting the heterogeneity of the studies, considering that the populations of the referenced surveys were composed of students with poor academic achievement or speech-language disorders and covered a broader age group, different from the sample of the present study, which included schoolchildren without complaints aged 8-10 years. It is worth noting that the aforementioned study was also conducted in a public school⁽¹²⁾, and that the highest scores in the frequency and duration pattern tests were obtained by schoolchildren without speech-language disorders, which differs from the findings of this study, in which students with normal RC presented inadequate performance in CATO skills.

Although the results of this pilot phase indicate feasibility of the study, there is need for stratification by gender, age, and school grade so that more robust evidence can be produced according to developmental chronicity parameters.

CONCLUSION

The present study demonstrated that one third of the investigated schoolchildren presented inadequate performance in simple and complex auditory temporal ordering skills, and that 4.5% of them showed altered performance in the WPRC test. However, no statistically significant correlation was observed between auditory temporal processing and reading competence.

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Author contributions

CAS was responsible for collection and analysis of data, writing of the manuscript and approval of its final version; *AGE* participated in the study orientation, collection and analysis of data, writing of the manuscript and approval of its final version; *SMAL* was responsible for the study design and orientation of all its phases, data analysis, writing of the manuscript and approval of its final version.