

Interference of phonological disorder on the reading of items with different psycholinguistic characteristics

Interferência do transtorno fonológico na leitura de itens com diferentes características psicolinguísticas

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ABSTRACT

Introduction: Speech disorders may impair the construction of phoneme-grapheme association and affect decoding and reading fluency. **Purpose:** To describe the performance profiles of schoolchildren diagnosed with reading disorder (RD) and with reading disorder associated with phonological disorder (PD) in the task of reading of isolated items according to the psycholinguistic characteristics of such items. **Methods:** The medical records of 36 schoolchildren enrolled at the 4th and 5th grades of elementary school were analyzed as follows: 18 children with RD were paired with other 18 children with typical development according to age, schooling, and gender. The study sample was divided into four groups: Study Group 1 (SG1), composed of 10 schoolchildren with RD; Study Group 2 (SG2), comprising eight schoolchildren with RD and PD; Control Group paired with SG1 (CG1); and CG paired with SG2 (CG2). The reading of words and pseudo words was compared with respect to orthographic regularity, frequency, and extension. The data were statistically analyzed. **Results:** Lower values of rate and accuracy were observed in the study groups compared with those of the control groups, except for the rate of pseudo words in SG2. The study groups showed lower statistical results than the control groups for all regularity variables, except for irregular words. SG1 and CG1 presented similar performance in the reading of monosyllabic and polysyllabic words. Regarding trisyllabic and dissyllabic words, significantly lower mean values were found in SG1 compared with those of CG1; however, SG2 showed significantly lower performance regardless of item extension. Performance of the study groups with respect to item familiarity was significantly lower for all variables, except for high frequency. **Conclusion:** Children with RD present good use of the lexical route and difficulty with the phonological route. Phonological speech disorder impairs the performance of schoolchildren on both reading routes.

Keywords: Reading; Cognition; Dyslexia; Articulation disorders; Speech, language and hearing sciences

RESUMO

Introdução: Transtornos de fala podem prejudicar a construção da associação fonema-grafema e afetar a decodificação e a fluência leitora. **Objetivo:** Descrever perfis de desempenho de escolares com diagnóstico de Transtorno de Leitura (TL) e de escolares com Transtorno de Leitura associado a Transtorno Fonológico (TF), em tarefa de leitura de itens isolados, segundo as características psicolinguísticas dos itens. **Métodos:** Foram analisados prontuários de 18 crianças com TL, pareadas por idade, escolaridade e gênero e à avaliação de outras 18, matriculadas no 4^o e 5^o ano do Ensino Fundamental (EF), assim distribuídas: Grupo Pesquisa 1 (GP1)=10 escolares com TL; Grupo Pesquisa 2 (GP2)=8 escolares com TL e TF; Grupo Controle pareado ao Grupo Pesquisa 1 (GC1) e Grupo Controle pareado ao Grupo Pesquisa 2 (GC2). Foram comparadas as leituras de palavras e pseudopalavras, classificadas segundo regularidade ortográfica, frequência e extensão. Os dados foram analisados estatisticamente. **Resultados:** Valores mais baixos de taxa e acurácia foram encontrados nos grupos pesquisa, quando comparados aos grupos controle, com exceção da taxa de pseudopalavras do GP2. Ambos os grupos pesquisa mostraram desempenho estatisticamente inferior aos controles para todas as variáveis de regularidade, exceto para palavras irregulares. GP1 e GC1 tiveram desempenho semelhante na leitura de palavras monossilábicas e polissilábicas; nas trissilábicas e dissilábicas, a média do GP1 foi significativamente inferior. Entretanto, o GP2 apresentou desempenho significativamente inferior, independentemente da extensão do item. Quanto à familiaridade, o desempenho dos grupos pesquisa foi significativamente inferior para todas as variáveis, exceto para alta frequência. **Conclusão:** Crianças com TL apresentaram bom uso da rota lexical e dificuldade para rota fonológica. O transtorno de fala de base fonológica prejudicou ambas as rotas de leitura.

Palavras-chave: Leitura; Cognição; Dislexia; Transtornos da articulação; Fonoaudiologia

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INTRODUCTION

According to the Simple View of Reading⁽¹⁾, reading is a cognitive competence aimed at comprehension and, to this end, it coordinates skills to decode writing and others related to the ability to process information to comprehend situations. Therefore, the performance of schoolchildren in reading comprehension can be easily explained by predictors such as decoding ability and oral comprehension. The decoding stages are fundamentally related to issues of phonological processing or representation. Phonological organization, a constituent of language, is the basis for speech development. Through this organization it is possible to reflect on the sound system of the language, identify each phoneme, develop conditions to understand the alphabetical principle of writing, and thus learn to read and write⁽²⁾.

It is expected that the presence of a speech disorder, of phonological nature, could undermine the phonological processing and, consequently, the learning of reading. In fact, it is possible to observe greater difficulty in learning, or even lower reading scores, when phonological representations, which are the substratum of formal information about written letters and words, are hindered by phonological disorders expressed in speech. Therefore, it can be observed that the learning of reading and writing demands good organization of the phonological system^(3,4,5,6).

The specific scientific literature shows that children with speech disorders often present deficits in speech perception and phonological awareness development, despite the fact that they present receptive language skills higher than the expected for their age⁽⁷⁾. These deficits can affect the proper identification of the sound characteristics of phonemes⁽⁸⁾, impairing the construction of the correct knowledge of the phoneme-grapheme association and, consequently, affecting decoding and reading fluency with regards to accuracy and reading rate⁽⁹⁾.

Adequate grapheme-phoneme conversion allows the reading of any regular word. This feature, commonly used at the beginning of learning, progresses in efficiency as readers become more agile to decode. Moreover, repeated exposure to words (with high frequency of occurrence in reading) enables readers to recognize the written word globally and automatically⁽¹⁰⁾.

The study of reading performance of isolated linguistic items proposes different cognitive models (or of another nature) that seek to explain the reading processes and the routes of recognition of written items. The Dual-Route Cascaded (DRC)⁽¹⁰⁾ is one of the most studied models, and the one that has best explained decoding skills⁽¹¹⁾. The DRC model advocates that reading occurs through two distinct routes (mechanisms): one dependent on phonological processing and the other on direct visual recognition (lexical)⁽¹¹⁾.

To evaluate reading and understand how readers recognize words, it is important to know which route they use while

reading. To this end, it is also necessary to analyze the characteristics of the linguistic items, such as familiarity - high or low frequency and pseudowords; orthographic regularity - related to the greater or lesser transparency of written language^(12,13); and extension - number of letters/syllables that compose the linguistic item⁽¹⁴⁾. These characteristics certainly influence the recognition of written words^(14,15).

Studies show lower latencies in the recognition of regular words compared with those of irregular ones, and in the reading of words compared with that of pseudowords⁽¹⁶⁾. These phenomena are classified as regularity effect and lexical effect, respectively. The lexical effect can be explained by the fact that familiar words are recognized through a direct and automatic process; this is not the case with pseudowords, whose access to phonological information inevitably occurs through a decoding process⁽¹⁷⁾. It is possible to verify a larger number of correct responses in the reading of frequent words compared with that of non-frequent ones - familiarity effect, as well as better performance in the reading of short words in comparison with that of long ones - extension effect⁽¹⁸⁾.

The hypothesis underlying the present study is the expectation that Phonological Disorder (PD) associated with Reading Disorder (RD) increase the risk or difficulty in phoneme-grapheme conversion, and may interfere more directly in the reading of regular words of greater extension and lesser familiarity, which would present lower reading accuracy mean values.

The objective of this study was to describe the performance profiles of schoolchildren diagnosed with RD and with RD associated with PD in the task of reading of isolated items according to the psycholinguistic characteristics of such items.

METHODS

This retrospective, case-control study was approved by the Research Ethics Committee of the aforementioned Institution under protocol no. CAAE: 47056415.5.0000.5505. The study was performed after the signature of the Declaration of Conformity for use of the collection of the Department of Speech, Language and Hearing Sciences, *Universidade Federal de São Paulo*, and of the Assent Form for use of research material.

The data sample consisted of information from 18 medical records of children evaluated and diagnosed with Reading Disorder (RD), with or without Phonological Disorder (PD), and from the assessment of 18 children paired with the first according to age, schooling, gender, and teaching network. The 36 participating schoolchildren were regularly enrolled in the 4th and 5th grades of public elementary schools (18 female students); the study and control groups were evaluated at different times.

The study sample was divided into four groups: Study Group 1 (SG1), composed of 10 schoolchildren with RD;

Control Group 1 (CG1), comprising 10 schoolchildren with typical development for rate and accuracy paired (1:1 ratio) according to gender, age, and schooling with SG1; Study Group 2 (SG2), composed of eight schoolchildren with RD and PD; Control Group 2 (CG2), comprising eight schoolchildren with typical development for rate and accuracy paired (1:1 ratio) according to gender, age, and schooling with SG2.

The following inclusion criteria were adopted to compose the sample: absence of complaints or indicators of hearing impairment; absence of complaints or indicators of visual impairment (uncorrected refractive error); absence of complaints or indicators of presence of neurological, behavioral or cognitive disorders; Informed Consent Form (ICF) signed by the participants' parents and/or guardians.

At the time of assessment, the schoolchildren in the control groups did not present history of low academic achievement or had previously undergone speech-language therapy. For the selection of these schoolchildren, the teachers were requested to identify students with good reading comprehension and academic performance attested by satisfactory grades in the Portuguese and Mathematics disciplines for two consecutive school bimesters. Data of the schoolchildren in the study groups were selected from the collection of speech-language pathology evaluations conducted in a reading and writing assessment and therapy outpatient clinic in Sao Paulo. These medical records contained information on assessments of oral communication - receptive and expressive, which included phonetic transcriptions taken from the application of the ABFW Test - Phonology⁽¹⁹⁾; written communication - receptive and expressive, which included audio recordings of the reading of 38 isolated words and 29 isolated pseudowords⁽²⁰⁾; and of hearing - audiometry, immitanciometry, and auditory processing.

Reading Disorder (RD) was defined according to the presence of the following manifestations observed in the speech-language pathology assessment: low values of rate and reading accuracy of words and pseudowords, associated with impairments of reading comprehension⁽²¹⁾; deficit of phonological processing skills (phonological working memory)⁽²²⁾, phonological awareness⁽²³⁾, and phonological lexical access⁽²⁴⁾. Phonological Disorder (PD) was identified according to the presence of one or more productive phonological processes, based on speech analysis, collected in naming and imitation tests⁽¹⁹⁾.

All schoolchildren read the same lists of 38 words and 29 pseudowords⁽²⁰⁾, written in Arial font, size 16, arranged vertically in double spacing - both lists balanced according to extension, frequency, and orthographic regularity.

Readings were recorded, canonically transcribed, and analyzed based on the criteria of psycholinguistic classification of items according to regularity, frequency, and extension of words⁽¹⁷⁾. Hesitations, review strategies for corrections, or failures in orthographic decoding identified in the analysis of the recordings were considered errors⁽²⁰⁾.

The means of correct responses were calculated according to the categories Familiarity - items of high, medium and low frequency and pseudowords; Orthographic regularity - regular, rule-based and irregular words; Extension - monosyllabic, disyllabic, trisyllabic and polysyllabic words⁽¹⁷⁾. In addition, the values of rate (number of words read per minute) and accuracy (number of correct words read per minute) were calculated from the following formulas, respectively: number of words read multiplied by 60, divided by the time spent reading (in seconds); number of words read correctly multiplied by 60, divided by the time spent reading (in seconds)⁽²¹⁾. The analyzed data were classified and submitted to descriptive and inferential statistical analysis.

Statistical analyses were conducted as follows: normality of the data was initially investigated by means of the Shapiro-Wilk test, in which variables with p values <0.05 were considered non-normal; subsequently, inferential analysis was performed using the t test for dependent (or paired) samples, for normal distribution variables, and the Wilcoxon test for non-normal distribution variables. The non-parametric Mann-Whitney test was applied to compare the groups. A significance level of 5% ($p<0.05$) was adopted for all statistical analyses.

RESULTS

Comparative study of the groups with respect to the reading of isolated items showed lower values of rate and accuracy for the study groups (SG1 and SG2) compared with those of their respective control groups, except for rate of pseudowords in SG2, which was similar to that of its control group (Table 1).

Performance of the study groups regarding reading, according to the regularity characteristics of psycholinguistic items, was statistically lower than that of their respective control groups for all variables analyzed, except for irregular words, whose comparison showed only a tendency for difference between SG1 and CG1 ($p=0.051$).

Regarding item extension, SG1 and CG1 presented the same performance in the reading of monosyllabic and polysyllabic words; however, the mean for SG1 was lower than that for CG1 in the reading of trisyllabic and disyllabic words. As for the performance of SG2, the group presented significant lower values than those of CG2 regardless of item extension (Table 2).

Performance of the study groups with respect to item familiarity was significantly lower for all variables compared with that of their control groups, except for high frequency, in which SG1 showed performance similar to that of CG1.

DISCUSSION

Co-occurrence of language developmental disorders seems to aggravate the already impaired performance conditions of students with Reading Disorder (RD) in reading decoding

Table 1. Mean values for rate and accuracy of words and pseudowords according to group of schoolchildren and comparisons between the groups

		SG1 (n=10)	CG1 (n=10)	CV and sig	SG2 (n=8)	CG2 (n=8)	CV and sig
Rate of words	Mean	25.10	40.30	t=-3.042	29.03	47.26	t=-2.718
	SD	9.315	10.730	p=0.014*	17.701	8.692	p=0.030*
Rate of pseudowords	Mean	20.40	32.50	t=-3.558	35.52	37.09	Z=-1.120
	SD	7.619	5.968	p=0.006*	34.475	5.277	p=0.263
Accuracy of words	Mean	14.10	30.80	t=-2.879	14.73	41.08	t=-4.690
	SD	10.959	13.555	p=0.018*	14.423	9.976	p=0.002*
Accuracy of pseudowords	Mean	6	17	t=-2.590	7.45	26.18	Z=-2.100
	SD	6.254	10.165	p=0.029*	11.078	7.717	p=0.036*

* Significant values ($p \leq 0.05$) – Wilcoxon and t tests

Subtitle: SD = Standard deviation; n = Sample absolute number; SG1 = Study group 1; SG2 = Study group 2; CG1 = Control group paired with SG1; CG2 = Control group paired with SG2; CV and sig = Coefficient of variation and statistical significance

Table 2. Mean values for the assessment of psycholinguistic items according to their orthographic characteristic and comparisons

Orthographic characteristic of items		SG1 (n=10)	CG1 (n=10)	CV and sig	SG2 (n=8)	CG2 (n=8)	CV and sig
Regular words	Mean	5.20	8.80		4.50	9.75	
	SD	2.741	2.251	t=-3.632	3.780	1.035	t=-3.789
	n	10	10	p=0.005*	08	08	p=0.007*
Irregular words	Mean	6.10	8.80		4.63	10	
	SD	3.446	2.486	t=-2.246	3.068	2.070	t=-3.803
	n	10	10	p=0.051#	08	08	p=0.007*
Rule-based words	Mean	5.80	9.80		5.38	11.63	
	SD	4.341	3.084	t=-2.547	4.565	2.264	Z=-2.383
	n	10	10	p=0.031*	08	08	p=0.017*
Monosyllabic words	Mean	0.70	1		0.38	0.88	
	SD	0.483	0.000	Z=-1.732	0.518	0.354	t=3.736
	n	10	10	p=0.083	08	08	p=0.007*
Disyllabic words	Mean	12.10	18.10		9.88	19.25	
	SD	6.420	3.665	t=-2.818	7.357	2.493	t=-2.635
	n	10	10	p=0.020*	08	08	p=0.034*
Trisyllabic words	Mean	3.80	7.50		4	9.75	
	SD	3.259	2.991	Z=-2.403	3.338	1.389	t=-16.167
	n	10	10	p=0.016*	08	08	p=0.000*
Polysyllabic words	Mean	0.50	0.80		0.38	1.75	
	SD	0.707	0.632	Z=-1.000	0.744	1.282	Z=-1.811
	n	10	10	p=0.317	08	08	p=0.070*

* Significant values ($p \leq 0.05$) – Wilcoxon and t tests

Marginally significant values

Subtitle: SD = Standard deviation; n = Sample absolute number; SG1 = Study group 1; SG2 = Study group 2; CG1 = Control group paired with SG1; CG2 = Control group paired with SG2; CV and sig = Coefficient of variation and statistical significance

tasks. Notwithstanding this finding and based on a theoretical model that seeks to explain the neurophysiological pathways of reading, it was hypothesized that, in the study sample, the presence of speech disorder characterized by difficulty in the grapheme-phoneme conversion would hamper the reading of regular words and words of greater extension and lesser familiarity, as well as of pseudowords.

Thus the low values of rate and accuracy observed in the reading of isolated items, characteristic of RD, confirmed the poor reading conditions of both study groups. As expected, comparison of the mean rate and accuracy values in the reading of isolated words showed significant differences, with worse performance of both study groups in relation to their respective controls^(25,26).

Table 3. Comparative data of the frequency variable for dependent samples

		SG1		CG1		CV and sig	SG2		CG2		CV and sig
		4 th grade	5 th grade	4 th grade	5 th grade		4 th grade	5 th grade	4 th grade	5 th grade	
HF	Mean	4.33	3.43	4.33	4.57	Z=-1.207 p=0.227	2.25	3.25	4.00	5.50	t=-3.347 p=0.012*
	SD	.577	1.988	.577	1.134		1.708	2.217	.816	1.000	
	n	03	07	03	07		04	04	04	04	
MF	Mean	2.67	.43	3.67	1.00	Z=-2.333 p=0.020*	1.00	.50	4.00	1.00	Z=-2.220 p=0.026*
	SD	.577	.535	.577	.000		1.155	.577	.000	.000	
	n	03	07	03	07		04	04	04	04	
LF	Mean	17.33	10.57	23.33	20.00	t=-2.803 p=0.021*	09	13	22.00	26.25	t=-3.785 p=0.007*
	SD	7.024	8.243	.577	6.807		9.487	8.257	4.830	2.363	
	n	03	07	03	07		04	04	04	04	
Pseudowords	Mean	7.00		15.40		t=-3.674 p=0.005*	6.75		20.00		Z=-2.383 p=0.017*
	SD	6.650		5.700			8.031		3.780		
	n	10		10			08		08		

* Significant values (p≤0.05) – Wilcoxon and t tests

Subtitle: HF = High frequency; MF = Medium frequency; LF = Low frequency; SD = Standard deviation; n = Sample absolute number; SG1 = Study group 1; SG2 = Study group 2; CG1 = Control group paired with SG1; GC2 = Control group paired with SG2; CV and sig = Coefficient of variation and statistical significance

However, as for the reading of pseudowords, essentially a task of phonological nature, differences were evidenced only when the accuracy variable was investigated. The group with Phonological Disorder (PD) presented rate similar to that of its control group, but the presence of speech disorder, associated with RD, was only correlated with the accuracy variable in the decoding of unfamiliar words. This unexpected result is similar to those observed for the performance of the study groups (SG1 and SG2), suggesting the absence of worsening of reading disorders in students with PD.

Comparative analysis between SG2 and CG2 shows that only the variable accuracy presented lower values for the reading of pseudowords, possibly owing to deficits resulting from PD, which alter the mental representation of the sounds of a given language as well as their production. Therefore, this condition would be associated with deficits in the processing of phonological information, determined by the unbalance of auditory memory inventory and mental representations of linguistic sounds⁽²⁷⁾. Phonological information is essential for the learning and development of reading, especially for the accuracy observed in assessment tasks, or in simple reading activities⁽⁵⁾. Absence of the PD effect on the reading rate could, in turn, be explained by variations in the capacity of phonological lexical access, which is an important factor in the causal model of reading impairment. Performance variations in this skill can substantially alter reading fluency values, determining the impact dimension on automaticity due to co-occurrence with phonological awareness changes⁽²⁸⁾ - a hypothesis raised but not verified in the present research. In general, better conditions for rapid phonological lexical access can provide higher rate values in the reading of pseudowords⁽²⁸⁾.

Regarding the orthographic characteristics of the items, it was possible to observe that performance as a function of regularity evidenced greater loss of the phonological route for SG1, an understandable result considering that phonological processing, which is fundamental for the processing of these items^(14,15), was impacted⁽²⁶⁾. Nevertheless, no statistically significant differences were found between SG1 and CG1 with respect to the reading of irregular words, considering that processing through the lexical route comprises global recognition of the items, to the detriment of the use of phonological information^(26,29).

With regards to the comparison between SG2 and CG2, the first differ from the latter, presenting worse performance in the reading of all word types. This finding should be interpreted from the perspective of the course of reading appropriation. Proficient readers initially develop reading through the phonological route, progressively influenced by a process of lexical development⁽¹⁰⁾ that is established by determination of the contextual skills capable of leading to self-correction in reading and, consequently, to self-reflection, which results in the understanding of orthographic decoding rules⁽¹⁶⁾. Therefore, if the grapheme-phoneme association is not well established, the whole process of reading development may be compromised.

The difference in performance between the groups, even in the reading of rule-based words, suggests that the worst performance in reading regular items may occur both to phonological route usage failures and to the progressive appropriation of the orthographic rules. Consequently, GP2 performance shows that reading has been impaired from its most fundamental skills. Expressive phonological deviations impact the development and alter the phonological

representations, exposing children to greater risks of reading problems⁽³⁰⁾. In addition, skills such as phonological awareness and phonological short-term memory also affect the processing of phonological information, generating broader impacts on reading. Disorder severity, nature of phonological exchanges, and the persistence of these disorders directly interfere with the course of reading appropriation and the possibility of compensating for these difficulties. When the extension effect was analyzed in this study sample, it was possible to observe that schoolchildren in SG1 showed inferior performance compared with that of its control group in disyllabic and trisyllabic words, but similar performance in monosyllabic and polysyllabic words. Regarding the comparison between SG2 and CG2, the latter presented worse performance regardless of the extension of the read stimulus, confirming the presence of greater reading performance losses in the presence of PD.

Investigation of the frequency effect of the reading items applied in this study showed that SG1 presented worse performance in the reading of low- and medium-frequency words and of pseudowords compared with that of CG1; this result confirms impairment of the reading phonological route in that group considering that the performance of students with RD was similar to that of their peers in the control group for the variable high frequency. Therefore, these schoolchildren have read familiar words as expected for their schooling, showing preferred use of the lexical route and easy recognition of previously learned words⁽¹⁶⁾. Schoolchildren with PD presented a larger number of errors for all categories. In the absence of good phonological skills, poor performance may lead to decoding errors, which hinder lexicalization owing to a probable restriction to the reading experience, with effect on the enlargement of the visual vocabulary of words, justifying the absence of positive familiarity effect⁽³⁰⁾. Performance of the study groups was worse than that of the control groups on the reading of pseudowords, confirming impairment of the phonological route in both conditions.

To discuss the reading processing and characterize the routes applied by each group of students, it is necessary to analyze the effects most commonly described in the literature^(10,14,18). Effects of regularity and extension are influenced by the use of the phonological process in reading, whereas frequency effects are indicators of the use of the lexical process, because the more familiar the item, the faster and more correct its recognition and production.

Comparison between the study groups did not show differences in all the psycholinguistic characteristics studied. It can be inferred that difficulty in the processing of phonological information as well as poorly established orthographic representations were present in both groups. Even in RD, in which phonological disorders are not evidenced in speech (as in PD), the underlying assessment identifies inadequacy of the same language subsystem, but in different instances of processing.

CONCLUSION

Schoolchildren with Reading Disorder present good use of the lexical route (irregular words and high frequency) and demonstrate greater difficulty in the decoding of items, which requires the use of the phonological route, possibly due to greater difficulty in both the processing of phonological information and to the absence of well-established orthographic representations.

Association of Phonological Disorder with Reading (and writing) Disorder determines poor performance in both reading routes owing to the impact of phonological impairment on learning, which hinders the phoneme-grapheme conversion, compromising the representations, access, and retrieval by access to the mental lexicon.

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