

Phonological processing: comparison between children with and without phonological disorder

Processamento fonológico: comparação entre crianças com e sem transtorno fonológico

Procesamiento fonológico: comparación entre niños con y sin trastorno fonológico

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Abstract

Introduction: Phonological disorder (TF, in Portuguese) is the failure to use speech sounds expected for the stages of development. Among the factors related to the development of oral language, there is phonological processing (PF, in Portuguese), formed by the abilities of lexical access, phonological memory and phonological awareness. **Objective:** To compare the performance of PF in children with and without TF, as well as to correlate PF skills with each other and with total phonological processing (PFT, in Portuguese). **Method:** Cross-sectional observational study. Twenty children between 5 years and 8 years old, boys and girls, were separated in the Research Group (GP) and Control Group (CG), respectively, in the presence or absence of TF. An evaluation of the abilities of the PF was performed with Quick Nomination Test, Brazilian Children's Test of Pseudoword Repetition and Phonological Consciousness Test. The data were analyzed statistically. **Results:** It was observed a higher prevalence of TF in males. The groups were statistically different in the lexical access, phonological memory and PFT abilities, with better performance for the GC. In GP, correlations were observed between the abilities of the PF, with the exception of phonological memory, which did not present correlation with age and

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phonological awareness. In GC, correlations between abilities were also observed, except for access to the lexicon, which showed correlation only with PFT. **Conclusion:** The GP children presented worse performance in the PF tests, except in phonological awareness, where the groups presented similar performances. PF skills showed correlations with each other, with some exceptions.

Keywords: Evaluation; Speech, Language and Hearing Sciences; Child Language; Speech Sound Disorder.

Resumo

Introdução: O transtorno fonológico (TF) é o fracasso no uso de sons da fala esperados para as etapas do desenvolvimento. Dentre os fatores relacionados com o desenvolvimento da linguagem oral, há o processamento fonológico (PF), formado pelas habilidades de acesso ao léxico, memória fonológica e consciência fonológica. **Objetivos:** Comparar o desempenho do PF entre crianças com e sem TF, bem como correlacionar as habilidades do PF entre si e com o processamento fonológico total (PFT). **Método:** Estudo observacional transversal. Participaram 20 crianças entre 5 anos e 8 anos, meninos e meninas, separados em Grupo Pesquisa (GP) e Grupo Controle (GC), respectivamente à presença ou ausência de TF. Foi realizada avaliação das habilidades do PF com Prova de Nomeação Rápida, Teste Infantil Brasileiro de Repetição de Pseudopalavras e Prova de Consciência Fonológica. Os dados receberam análise estatística. **Resultados:** Foi observada maior prevalência do TF no sexo masculino. Os grupos se mostraram estatisticamente diferentes nas habilidades de acesso ao léxico, memória fonológica e no PFT, com melhor desempenho para o GC. No GP, foram observadas correlações entre as habilidades do PF, com exceção da memória fonológica, que não apresentou correlação com idade e consciência fonológica. No GC, também foram observadas correlações entre as habilidades, com exceção do acesso ao léxico, que apresentou correlação apenas com PFT. **Conclusão:** As crianças do GP apresentaram pior desempenho nas provas do PF, exceto em consciência fonológica, onde os grupos apresentaram desempenhos semelhantes. As habilidades do PF mostraram correlações entre si, com algumas exceções.

Palavras-chave: Avaliação; Fonoaudiologia; Linguagem infantil; Transtorno fonológico.

Resumen

Introducción: El trastorno fonológico (TF) es el fracaso en el uso de sonidos del habla esperados para las etapas del desarrollo. Entre los factores relacionados con el desarrollo del lenguaje oral, hay el procesamiento fonológico (PF), formado por las habilidades de acceso al léxico, memoria fonológica y conciencia fonológica. **Objetivos:** Comparar el desempeño del PF entre niños con y sin TF, así como correlacionar las habilidades del PF entre sí y con el procesamiento fonológico total (PFT). **Método:** Estudio observacional del tipo transversal. Participaron 20 niños entre 5 años y 8 años y 11 meses, niños de 5 a 8 años, niños y niñas, separados en grupo de investigación (GP) y grupo control (GC), respectivamente, a la presencia o ausencia de TF. Se realizó una evaluación de las habilidades del PF con Prueba de Nombramiento Rápido, Prueba Infantil Brasileña de Repetición de Pseudopalabras y Prueba de Conciencia Fonológica. Los datos recibieron análisis estadísticos. **Resultados:** Se observó mayor prevalencia del TF en el género masculino. Los grupos se mostraron estadísticamente diferentes en las habilidades de acceso al léxico, memoria fonológica y en el PFT, con mejor desempeño para el GC. En el GP, se observaron correlaciones entre las habilidades del PF, con excepción de la memoria fonológica, que no presentó correlación con edad y conciencia fonológica. En el GC, también se observaron correlaciones entre las habilidades, con excepción del acceso al léxico, que presentó correlación sólo con PFT. **Conclusión:** Los niños del GP presentaron peor desempeño en las pruebas del PF, excepto en conciencia fonológica, donde los grupos presentaron desempeños similares. Las habilidades del PF mostraron correlaciones entre sí, con algunas excepciones.

Palabras claves: Evaluación; Fonoaudiología; Lenguaje Infantil; Trastorno Fonológico.

Introduction

Over the last two decades, language acquisition, including phonological acquisition, has received much research attention. Concerning the Brazilian Portuguese, much research that document aspects of phonological development is recent^{1,2}.

Phonological acquisition is a gradual, non-linear, and with individual variation process, meaning that it does not happen in the same way for everyone. The age required to achieve phonological mastery has not yet received much research attention, but it is believed that children achieve mastery at 5 years old³.

During phonological acquisition, phonological processes are used, using predictable processes according to the age range, but disappearing as children mature. Therefore, when these patterns persist and become inadequate for the age range, there is a disorder called phonological disorder (PD)³.

PD is a failure to use speech sounds expected for the stages of development, characteristically of the individual's age and dialect. It can involve errors in the production, use, and representation or organization of the phoneme, such as sound omissions or sound substitutions⁴.

Over the years, these inadequacies when producing speech sounds have received many denominations, amongst them, one can cite: dyslalia, phonological disorder, phonological deviation, and speech disorder, with the last three being considered as synonyms according to studies in this field^{1,5}.

Many factors are related to phonological development. Among them are the phonological processing (PP) abilities. This processing is related to the use of sound information from a language and it shows three abilities: lexical access, phonological memory, and phonological awareness⁶⁻⁸.

Lexical access refers not only to the velocity, but also to the facility to access information stored in long-term memory. This ability is formed by three essential stages: object identification, lexical access of its name, and answer's generalization. Hence all these stages should be achieved so the individual gets organized from a phonological and articulatory point of view, and then, give a proper answer^{9,6}.

Phonological memory is the term used to designate the work memory component used in verbal material processing⁶. By evaluating this ability, it is

possible to comprehend if the individual can retain and recover verbal presentations from short-term memory¹⁰.

In the other hand, phonological awareness consists of the ability to perceive that speech consists of different segments until achieving the littlest unities (phonemes). Besides perception, it is also the ability to manipulate speech sounds: to add, to segment, to transpose and replace syllables and phonemes, to identify and produce rhymes and alliterations, among others⁹.

Since 1980, it is studied the hypothesis that an auditory-sensory deficit has an impact on speech sounds perception. Therefore, children with PD would have trouble to perceive and distinguish properly these sounds within the speech spectrum, and after, to develop the phonological representation of each one of them to produce them correctly. In this way, there is a strong connection between PP and PD difficulties¹¹.

Based on the assumption that PP is directly related to phonological development, this present study aimed to compare the phonological processing performance between children with and without phonological disorder, as well as to correlate phonological processing abilities among each other and with the broad category of phonological processing (BCPP), which means the phonological processing analyzed as a whole.

Method

The protocol of this research was approved by the Ethics Committee in Research of the Universidade Estadual de Ciências da Saúde de Alagoas (UNCISAL) under protocol number 1.930.476.

A cross-sectional observational study was conducted with children ranging from 5 years and 1 month old to 8 years and 11 months old. Those responsible for the children who participated in the study received all the information and clarifications about the voluntary participation in the study, its goals, risks and benefits, and they signed a free informed consent form.

The study subjects were divided into two groups: research group (RG), composed by 10 children with PD, and control group (CG), composed by 10 children without PD. A pairing between the groups was done, in the proportion of 1:1, according to sex and age.

Children from RG were selected from a waiting list of a Specialized Rehabilitation Center level III of a Brazilian northeastern capital. To compose the CG, there were chosen children from a local school in the same capital and same region of the rehabilitation center. The aim was to guarantee the homogeneity of the sample, based on social and economic similarities.

The following were considered inclusion criteria: children that were in the waiting list waiting for speech therapy at the rehabilitation center until March 2017, with the complaint of speech errors, and students from a local school of a Brazilian northeastern capital. Exclusion criteria were: children with complaints of neurological, cognitive, auditory or visual alterations, history of motor development alterations, and below-average performance in receptive vocabulary.

To access these criteria, those responsible for the children were interviewed through a form prepared by the authors with questions concerning the prenatal, perinatal and postnatal period, psychomotor and auditory development, schooling and language complaints; and a receptive vocabulary evaluation, using the Peabody Picture Vocabulary Test (PPVT)¹².

Initially, 38 children were selected from the waiting list for the RG. Of these, 23 attended the selection interview to participate in the research. After the selection process, 12 children, who presented a below-average PPVT result, and 1 child, who presented a hearing loss, were excluded. Therefore, 10 children participated in the study, 3 females and 7 males.

In order to compose the CG, an initial contact was carried out with teachers from a local school, and they indicated 21 students that matched the profile sought according to the inclusion criteria. Considering the pairing, 10 children were selected to participate in the study.

To diagnose the PD, the participants underwent speech evaluation through the ABFW Test – Phonology¹³, which aims to verify the child's phonetic inventory, as well as the phonological rules used, their distribution, and the type of syllabic structure observed. At the time of the evaluation, all the responses were recorded (on a mobile phone) for later transcription on the record sheet and analyzed according the test instructions. In addition, a hearing evaluation through tonal and vocal audiometry and immitanciometry was carried out at the same

rehabilitation center in which the children were on the waiting list.

For data collection, children underwent phonological processing evaluation through the following tests: Rapid Automatized Naming (RAN)¹⁴ (only the objects section), Brazilian Children's Test of Pseudoword Repetition (BCPR)¹⁵ and Phonological Awareness Test (PAT)¹⁶, which aims to evaluate, respectively, velocity of mental lexical access, phonological memory, and phonological awareness.

For all the tests, a point was assigned when the task was performed properly, according to what was required. Thus, in the RAN test, children could make a total of 36 points; while in the BCPR and PAT tests, children could make a total of 40 points in each. In order to analyze the broad category of phonological processing, the sum of correctness of the three tests was performed, leading to a maximum of 116 points.

After the described evaluations, those responsible for the children received a speech-language assessment report from the authors containing all the tests results, and orientations and questions were clarified when needed.

All the data were tabulated and analyzed with the statistical package BioEstat 5.0. An α value of 0.05 was considered statistically significant, and it was marked with an asterisk (*).

Data were described into tables presenting the means and standard deviations. Lilliefors test was used to test if the characteristics of the sample came from a population with normal distribution. The results indicated that the variable Phonological Awareness in the RG did not show normal distribution. Therefore, statistical analysis was performed using nonparametric tests.

The Mann-Whitney test was used to analyze the intergroup variables. For the correlation of variables, in both groups, Spearman's Rho (Rs) was used. For results less than 0.20, correlation is negligible; if Rs is between 0.20 and 0.40, the correlation is weak; values between 0.40 and 0.60 represent moderate correlation; between 0.60 and 0.80 the correlation is considered strong; and if Rs is greater than 0.80, the correlation is very strong¹⁷.

Results

Twenty children participated in the study, distributed equally into RG and CG, according to

the presence or not of PD, paired in the proportion of 1:1, according to sex and age.

Table 1 shows children distribution of the RG and CG according to age, sex, and percentage of correct answers in each ability of the PP and the BCPP.

It can be observed that there was a greater prevalence of males than females, as well as the

age group from 7 years old to 8 years and 11 months old.

In the context of the percentage of correct answers in each ability of PP and BCPP, it was possible to verify that all children from the CG presented a better performance than those from the RG. The phonological awareness test showed the lowest percentages of correct answers.

Table 1. Percentage distribution of correct answers of all the subjects from the research group and the control group in lexical access, phonological memory and phonological awareness abilities, and in the broad category of phonological processing.

Subject	Age (years)	Sex	LA (%)	PM (%)	PA (%)	BCPP (%)
RG01	5	M	36.11	10.00	7.50	17.24
CG01			69.44	85.00	40.00	64.65
RG02	5	M	2.77	85.00	5.00	31.89
CG02			86.11	90.00	25.00	66.37
RG03	6	M	50.00	60.00	20.00	43.10
CG03			91.66	87.50	27.50	68.10
RG04	7	M	41.66	22.50	12.50	25.00
CG04			88.88	90.00	57.50	78.44
RG05	7	M	58.33	37.50	62.50	52.58
CG05			91.66	100.00	77.50	89.65
RG06	7	M	63.88	80.00	65.00	69.82
CG06			80.55	100.00	77.50	86.20
RG07	7	F	91.66	90.00	50.00	76.72
CG07			97.22	100.00	72.50	89.65
RG08	7	F	75.00	80.00	62.50	72.41
CG08			80.55	95.00	57.50	77.58
RG09	8	M	58.83	67.50	72.50	66.37
CG09			97.22	100.00	77.50	91.37
RG10	8	F	77.77	87.50	70.00	78.44
CG10			91.66	95.00	70.00	85.34

Legend: RG = research group; CG = control group; LA = lexical access; PM = phonological memory; PA = phonological awareness; BCPP = broad category of phonological processing.

Table 2 shows the comparison of the absolute means of correct answers of the RG and the CG in the PP abilities and BCPP. The groups were statistically different when comparing lexical access, phonological memory abilities, and BCPP, with

better performance for the CG. There was no difference in performance when comparing phonological awareness between the groups, with low absolute means of correct answers in both.

Table 2. Intergroup comparison of mean values of correct answers in lexical access, phonological memory, phonological awareness, and in the broad category of phonological processing.

	Group	Mean	SD	p-value
LA	GP	20.00	9.01	0.0017*
	GC	31.50	3.10	
PM	GP	24.80	11.55	0.0007*
	GC	37.70	2.31	
PA	GP	17.10	11.19	0.1306
	GC	23.30	8.26	
BCPP	GP	61.90	26.37	0.0082*
	GC	92.50	11.93	

*Significant values ($p \leq 0,05$) – *Mann - Whitney Test*

Legend: RG = research group; CG = control group; LA = lexical access; PM = phonological memory; PA = phonological awareness; BCPP = broad category of phonological processing.

Table 3 shows the analysis of the correlations among age, PP abilities, and BCPP in the RG. The presence of positive correlations between the vari-

ables was observed, with exception of phonological memory, which did not present correlation with age and phonological awareness.

Table 3. Correlations among phonological processing abilities, the broad category of phonological processing, and age in the research group.

		Scores – Phonological Processing Abilities			
		LA	PM	PA	BCPP
Age	Rs	0.0275*	0.3778	0.0005*	0.0252*
		0.6889	0.3134	0.8946	0.6966
LA	Rs	-----	0.0489*	0.0247*	<0.0001*
		-----	0.6341	0.6982	0.9483
PM	Rs	-----	-----	0.4067	0.0065*
		-----	-----	0.2957	0.7903
PA	Rs	-----	-----	-----	0.0166*
		-----	-----	-----	0.7295

*Significant values ($p \leq 0,05$) – *Spearman Coefficient*

Legend: Rs = Spearman correlations with p-value; LA = lexical access; PM = phonological memory; PA = phonological awareness; BCPP = broad category of phonological processing.

Table 4 presents the analysis of the correlations among age, PP abilities and BCPP in the CG. It was observed the presence of positive correlations

among the variables, except for lexical access, which presented correlation only with BCPP.

Table 4. Correlations among phonological processing abilities, the broad category of phonological processing, and age in the control group.

		Scores – Phonological Processing Abilities			
		LA	PM	PA	BCPP
Age	Rs	0.0967	0.0306*	0.0143*	0.0058*
		0.5538	0.67 94	0.7404	0.7967
LA	Rs	-----	0.1469	0.2544	0.0216*
		-----	0.4937	0.3981	0.7091
PM	Rs	-----	-----	0.0004*	0.0001*
		-----	-----	0.9012	0.9217
PA	Rs	-----	-----	-----	0.0002*
		-----	-----	-----	0.9136

*Significant values ($p \leq 0,05$) – Spearman Coefficient

Legend: Rs = Spearman correlations with p-value; LA = lexical access; PM = phonological memory; PA = phonological awareness; BCPP = broad category of phonological processing.

Discussion

Acknowledging the limitations of this study regarding the size of the sample, the investigation shows, in its distribution, a proportion of PD of 70% males and 30% females (Table 1). The literature indicates a greater presence of speech disorders in males; three studies¹⁸⁻²⁰ with larger samples also demonstrated this same finding. Thus, it is possible to confirm that PD is more prevalent in males than in females.

The literature reports that language acquisition occurs differently between the sexes, since it is believed that the male brain has a slower maturation, thus, the girls present a superior development of language abilities¹⁸. This justifies the fact that boys present higher prevalence not only of PD, but also of other language disorders.

The percentage of correct answers in PP abilities and BCPP, presented in Table 1, showed better performance of children in the CG when compared with their RG pairs. For both groups, phonological awareness was the ability that presented the worst percentage of correct answers. This result is statistically confirmed in Table 2, which shows better performance of the CG in PP abilities and BCPP, except for phonological awareness.

This finding is contrary to what it was expected, since previous studies^{7,21,22,23} show a deficit in phonological awareness abilities in children with PD when compared with CG. However, it is likely that the similarity between the groups in this ability was due to the low values of means for correct answers presented in both.

This result is very worrying if we consider the relationship between phonological awareness abilities and reading and writing acquisition, as pointed out in the literature²⁴⁻²⁷. Thus, we verified that it is a possible that children from both groups present problems with the schooling process. In addition to this possibility, it is worth mentioning that schools in the Northeastern capital where the study was conducted usually do not focus on phonemic issues, so these low results may also be related to this aspect.

The comparison of lexical access between the groups showed that they behave differently, with better results for the CG. This result corroborates a study published in 2008⁶, which aimed to analyze the performance of children with and without PD on the task of Rapid Automatized Naming of objects.

The difference observed between the groups regarding lexical access may be related to the fact that children with PD present speech errors, which reflect the disorganization of the phonological system, and this may be related to alterations in the phonological representation of the lexical item, thus contributing to the slowness of lexical access in subjects with this disorder²⁸. Therefore, lexical access is one of the abilities impaired in PD and it needs to be evaluated, so that it can be improved in speech therapy with these subjects.

Findings on phonological memory in the intergroup comparison showed that children from the CG had a greater number of correct answers when compared with those from the RG, and this difference is statistically significant, as found in a study published in 2014⁷, which investigated phonologi-

cal memory ability in children with PD. Despite not having a CG, the authors of this study compared the results found with those from children with adequate phonological development described in other Brazilian studies. The authors concluded that children with PD present an inferior performance in the phonological memory test.

Therefore, phonological memory is related to phonological development and to the fast access of phonological and articulatory properties of the language. Thus, the better the articulatory skills of the individual, the greater the ease to produce pseudowords before the time to store the item to be repeated in memory exceeds.

In the prism of correlations, it was possible to verify that age correlated with all PP abilities, except phonological memory in the RG and lexical access in the CG. As children get older, it is expected that linguistic and metalinguistic abilities will improve in a general way by social interactions and the schooling process^{7,28}. The non-correlation with phonological memory in the RG may be due to the fact that phonological memory depends heavily on phonological representations, when dealing with pseudowords. So, regardless of the subject's age, their phonological memory would be impaired as a result of PD. On the other hand, the lack of correlation between lexical access and age in the CG may be related to the fact that only objects access was tested, which is an easy task for children without speech impairments, regardless of age.

The correlation found between age and lexical access in the RG is due to the fact that, with age, naming pictures becomes more efficient and phonologically more precise^{6,28}. Meanwhile, the correlation between age and phonological awareness in both groups is explained by the literature in this field when affirming that there is an evolution in phonological awareness as the children get older³⁰. This can be understood by taking into account the schooling process, because as time goes by, children at school will have more contact with questions concerning phonological awareness, getting better in this aspect.

A strong positive correlation between age and phonological memory in the CG is refuted by a study published in 2009³¹, in which the authors concluded that in their sample there was no statistically significant difference between these variables. However, it is worth mentioning that although this study had a larger sample (227 children), it had

only two age groups (7 years and 11 months old and 8 years and 11 months old), which probably justifies this result.

Lexical access presented a correlation with phonological memory, phonological awareness and BCPP in the RG, while in the CG, it only showed correlation with BCPP. The correlation between PP abilities was expected, as it was verified in another study²⁴, because these integrated abilities constitute the phonological basis of information processing, since it is only possible to access and manipulate information that is stored in a wholesome memory system³². Therefore, no argument was found to justify the fact that no correlation was found between phonological processing abilities in the CG.

Phonological memory presented a positive correlation with phonological awareness and with BCPP in the CG, and did not present a correlation with phonological awareness in the RG. Phonological memory is required when the child needs to perform phonological awareness tasks and, therefore, the presence of a correlation between both is expected, as observed in the CG and indicated by the literature^{7,33}, which states that phonological memory is important and is necessary for the execution of awareness tasks of the sound structure of words, since it requires a more detailed analysis of the segmental and phonemic nature of language, making it easier or more difficult depending on the literacy phase in which that subject is.

The lack of correlation between phonological memory and phonological awareness in the RG may be related to PD causing disorganization in the phonological system as a whole, interfering in the way sound is perceived, recorded, represented and produced, thus affecting the instability of the phonological processing, which may generate unexpected results in the correlations, such as those observed in the RG.

All variables were positively correlated with BCPP in both groups, which was expected, considering that the BCPP is formed by joining all the abilities that make up the PP; thus, lexical access, phonological memory and phonological awareness present a directly proportional relation with BCPP. This result was also verified in a study published in 2012²⁴, which found correlations between PF abilities and BCPP.

Conclusion

Given the above, it can be concluded that the group of children with phonological disorder presented a worse performance in phonological processing tests when compared to the group of children without speech impairments, except for the phonological awareness ability, in which both groups presented similar performances. Some phonological processing abilities showed correlations between them and all the abilities showed correlation with the phonological processing as a whole.

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