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Auditory-perceptual performance in children with and without phonological disorder in the stops class

Desempenho perceptivo-auditivo em crianças com e sem transtorno fonológico na classe das oclusivas

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Keywords

Phonological Disorder
Child
Auditory Perception
Evaluation
Speech

ABSTRACT

Purpose: To compare the auditory-perceptual performance of children with and without phonological disorder (PD) in the identification task of contrasts between stops phonemes. **Methods:** Information was selected from a database regarding the auditory-perceptual performance of 46 children (23 with a diagnosis of PD with involvement in the stops (G1) and 23 with typical speech development (G2)), aged 4 and eight years old, in an identification task of the class of stops consonants in Brazilian Portuguese, using the speech perception assessment instrument (PERCEFAL). The reaction time, the number of errors and correctness, as well as the pattern of perceptual error were considered in the analysis. **Results:** Regarding the auditory-perceptual accuracy, T-Test showed a statistically significant difference, in which typical children had a higher average of correctness than children with PD and shorter reaction time for correct answers. Regarding the error pattern, repeated measures ANOVA showed a significant effect for the group and error pattern, but not for the interaction between group and error pattern. Tukey's Post Hoc test showed for both groups that errors involving place of articulation were superior to voicing and voicing + place of articulation errors. **Conclusion:** children with phonological disorders have worse accuracy in relation to children without disorders and, also, longer response time for correctness. Errors involving the place of articulation between the stops were the most frequent for both groups.

Descritores

Transtorno Fonológico
Criança
Percepção Auditiva
Avaliação
Fala

RESUMO

Objetivo: Comparar o desempenho perceptivo-auditivo de crianças com e sem transtorno fonológico (TF) na tarefa de identificação dos contrastes entre os fonemas oclusivos. **Método:** Foram selecionadas, de um banco de dados, informações referentes ao desempenho perceptivo-auditivo de 46 crianças (23 com diagnóstico de TF com acometimento nas oclusivas (G1) e 23 com desenvolvimento típico de fala (G2)), entre quatro e oito anos de idade, em uma tarefa de identificação na classe das consoantes oclusivas do Português Brasileiro, a partir do instrumento de avaliação de percepção de fala (PERCEFAL). O tempo de reação, os números de erros e acertos, bem como o padrão de erro perceptual foram considerados na análise. **Resultados:** Com relação à acurácia perceptivo-auditiva o Test-T mostrou uma diferença estatisticamente significante, em que as crianças típicas tiveram uma média de acerto maior do que as crianças com TF e um tempo de reação menor para os acertos. No tocante ao padrão de erro a ANOVA de medidas repetidas mostrou um efeito significativo para o grupo e padrão de erro, mas não para a interação entre grupo e padrão de erro. O teste Post Hoc de Tukey mostrou para ambos os grupos que os erros envolvendo ponto articulatório foram superiores aos erros de vozeamento e vozeamento + ponto articulatório. **Conclusão:** crianças com transtorno fonológico apresentam pior acurácia em relação às crianças sem alteração e, ainda, um maior tempo de resposta para os acertos. Erros envolvendo o ponto de articulação entre as oclusivas foram os mais frequentes em ambos os grupos.

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INTRODUCTION

Phonological disorder (PD) is characterized by an maladjustment, disorganization or abnormality in the child's sound system in relation to the adult target pattern, without any organic impairment from the children[1]. The presence of errors in the production of speech sounds that are no longer expected for the child's age is observed in this case, suggesting a cognitive-based problem that involves a deficit in the linguistic categorization of sounds[2]. As this disorder does not have a well-defined cause, some national and international have sought to identify which factors could be correlated to the occurrence of such disorder[3-10].

Among the possible etiological factors, some authors[3,4] highlight the fact that children with phonological disorders might also have difficulties in the auditory-perceptual domain, and the difficulty in understanding speech sounds could be related to the occurrence of phonological disorders during childhood[5]. A previous study, for example, evaluated the performance in the auditory discrimination ability of children with typical and deviant phonological development. As a result, the authors found that children with PD often have difficulty in the auditory discrimination ability, suggesting difficulties in discriminating the voicing and place of articulation of the phonemes. The conclusion of this study was that subjects with PD have difficulties in perceiving minimal acoustic differences in speech, which is fundamental for the correct production of speech sounds[6].

Another study, on the other hand, evaluated the auditory processing of children with PD to observe some factors of organic-physiological etiology that could be related to such disorder. As a general result, the authors reported a high percentage of error from the disordered children for the dichotic listening tests: Staggered Spondaic Word (SSW), dichotic digit test and simplified digit evaluation, as well as the quantitative data were quite below the expected for the normality pattern, identifying a large number of omissions and substitutions to the words presented in the test. Moreover, children with PD needed a longer time to answer, thus suggesting that children with PD would have difficulties in auditory abilities related to analysis and auditory synthesis, temporal ordering and memory, since in this test, participants were instructed to repeat the words/digits in the order in which they were showed[7]. Such findings converge to similar results from previous studies, which point to the presence of disorder in central auditory processing for children with phonological disorder verifying changes in the P300 wave, with the increase of latency[8], as well as the presence of correlation between auditory processing disorder and severity of phonological disorder, in which children with auditory processing disorder tend to have greater severity in phonological disorder[9].

Recently, a study whose one objective was to investigate whether Australian children with and without PD differed in the general accuracy of speech perception, found a significantly worse auditory perceptual accuracy from children with PD when compared to the control group in a task of lexical and phonic judgment, thus suggesting that children with PD perceive speech less accurately than their typically developed peers. Another aspect observed in this same study was the existence of a correlation between production errors and perception errors shown by the groups (control and experimental). The phonemes /ɹ/ and /s/ showed worse accuracy in both groups, regarding production and perception[10].

Thus, published studies converge towards a possible relation between auditory perception and PD, once deficits in auditory-perceptual abilities could impair the ability to discriminate and process speech sounds, possibly affecting the production of these sounds. However, there are few studies that assess how children with PD perceive auditory stimuli in other perceptual skills, particularly in the identification of phonological contrasts, which may be correlated with this disorder.

It is noteworthy that the stops class has acoustically a long period of silence, corresponding to the blocking of articulators, and a very short time of acoustic information that differentiates them (explosion and formant transition), which makes this sound class quite interesting for investigation.

Assuming that PD would affect the perception of phonological contrasts, it is expected that the perceptual performance of children with PD in the identification task will be more laborious and less accurate. Consequently, it is estimated that the performance of children with PD is characterized by worse accuracy and longer reaction time.

Therefore, this study aimed to (a) compare the auditory-perceptual performance of children with and without phonological disorder in a task of sound identification, involving the stops phonemes of Brazilian Portuguese; (b) to identify the similarity (or not) of the error pattern shown by children with and without PD in the identification task of stops.

It is expected that the achievement of these objectives can lead to scientific gains, such as: identifying the factors correlated to Phonological Disorder, particularly regarding the ability to identify stops contrasts, as well as providing subsidies that can assist in therapeutic practice.

METHODS

Retrospective cross-sectional study, approved by the Research Ethics Committee (REC) of the Faculty of Philosophy and Sciences - Unesp, Campus of Marília, under Certificate of Presentation for Ethical Consideration (CPEC): 67549317.5.0000.5406, conducted after all those responsible for the study participants had signed the informed consent form.

Subjects

This study was conducted with 46 children (34 males and 12 females), aged 4 and 8 years old, 23 of whom were diagnosed with phonological disorder with involvement in the stops class (G1) and 23 with typical speech development (G2). Children in G1 were selected from the Supervised Speech Therapy Internship: Clinical Phonology at the Health Education Studies Center (centro de Estudos da Educação da Saúde - CEES), UNESP Marília; while data related to children with typical language development were selected from the database regarding auditory-perceptual performance to the stops class.

The children who obtained the diagnosis of Phonological Disorder with involvement of stops without any associated auditory disorder were selected for the composition of Group 1 (G1) and those who underwent the PERCEFAL test for the stops; while in Group 2 (G2), children who could be matched to children in group 1 regarding age and gender and those who had previously undergone hearing screening with normal results were selected.

As a sample exclusion criterion, similar parameters were adopted for both groups, thus excluding children with phonological disorders associated with other language disorders, neurological and/or auditory disorders and those whose performance in the word recognition stage of the applied test, it did not reach 80% of correctness before the presented stimuli.

Materials

Data regarding the auditory perceptual performance of the stops were obtained using the PERCEFAL instrument[11] through the PERCEVAL software (Perception Evalution Auditive & Visuelle)[12], the same used in previous studies[11,12].

The realization of this experiment involves 30 words (15 contrasting pairs) familiar to the children's vocabulary, which can be represented through figures, paroxytone syllables, with stops consonants in the stressed syllable. Ie: **B**erço, **P**ote, **D**ucha, **C**ola, **G**ola.

This instrument is composed of visual and auditory stimuli. The auditory stimuli comprise editions of recordings of the target words by an adult typical speaker of BP, while the visual stimuli comprise the pictures retrieved from the Google search site[13]. Such pictures make direct correspondence to the target words that constitute the test, that is, for each target word there is a corresponding image.

Procedure

The auditory-perceptual test proposed for this study refers to an identification test, which a choice is made through the sound-picture relation. The experiment has 3 stages: word recognition, training stage and test stage.

In the 1st stage, nown as the recognition phase, visual and auditory inputs are shown to participants in the test. This process investigates the child's familiarity with the stimuli. If the child does not recognize 80% of the stimuli presented, he/she was excluded from the experiment.

The training stage corresponds to the 2nd stage of the test. This stage is performed automatically by the software to ensure understanding of the identification task, and 10 stimuli are selected randomly by the software. The auditory and visual inputs are presented almost simultaneously, so that right after the presentation of the sound stimulus (target word), two pictures (corresponding to minimum pairs) are displayed on the computer screen, with only one corresponding to the sound stimulus. After the presentation of stimuli, the child must choose the corresponding picture, pressing a previously key combined. However, at this stage, the results obtained are not computed by the software. Once the participants' understanding of the task is guaranteed, the test stage itself begins.

The test stage corresponds to the last stage of the experiment, where children remained comfortably arranged in front of a computer screen with Koss headphones attached to their ears, in the acoustic treatment room at the CEES acoustic analysis laboratory. The children listened individually (with binaural presentation, at 50 DB SPL), one of the words of the minimum pair, and then had to decide and indicate a picture, in front of two arranged on the computer screen, pressing a key previously combined.

For example, the word "pato" was audibly presented and then pictures corresponding to the words "pato" and "gato" were displayed on the computer screen, so that the participant could decide and indicate which of the pictures would correspond to the auditory stimulus presented.

Both the presentation time of auditory and visual stimuli, as well as the response time were measured automatically by the PERCEVAL software.

The experiment lasted an average of 15 minutes per child regarding the three stages.

Analysis of data

As proposed in the PERCEFAL instrument[11], the following criteria were applied for analysis: (a) auditory-perceptual accuracy (percentage of errors, correctness and non-response); (b) reaction time for errors and correctness; and (c) error pattern characterized by (Voicing/ Place of articulation/ Voicing + Place of articulation). Pattern of voicing error are characterized by errors involving exclusively the contrasts between voiceless and voiced phonemes, for example, [p] and [b], [t] and [d], [k] and [g] while error patterns involving the place of articulation are characterized by contrast errors between the place of articulation, for example, [p] and [t], [b] and [d], [g] and [b]. However, in errors involving voicing + place of articulation, as the name suggests, the error is characterized by error patterns at both place of articulation and voicing level, for example, [p] and [d], [g] and [t], [b] and [t].

After tabulating and organizing the data in an Excel spreadsheet, a descriptive and inferential statistical analysis was conducted. In the inferential analysis, the reaction times of the errors and correctness were compared, as well as the auditory-perceptual accuracy between two groups of children (G1 and G2), using the T-test. Repeated Measures ANOVA was used to analyze the error pattern, considering the clinical condition of children (typical and with PD) as an inter-group factor and the type of error as the intra-group factor: voicing, place and place + voicing. An alpha value ≤ 0.05 was used.

RESULTS

To present the results, it will elucidate the research objective. This study aimed to compare the auditory-perceptual performance of children with and without phonological disorder, as well as to identify the similarity (or not) of the error pattern shown by children with and without PD in a task of sound identification, involving the stops phonemes of Brazilian Portuguese.

Table 1. Auditory-perceptual accuracy for the control (G1) and experimental (G2) groups

	G1	G2	Value T	p
	Mean (SD)	Mean (SD)	(df)	
% correctness	90.3 (8)	81.5 (16)	2.3 (44)	**0.02**
% error	8.4 (7)	13.9 (10)	-2.2 (44)	**0.03**
RT correctness (ms)	1702.6 (408)	1935.6(374)	2 (44)	**0.04**
RT error (ms)	1925.8 (478)	2159.8 (599)	-1.3 (38)	0.2

Caption: G1 = Control Group; G2 = Experimental Group; RT = Reaction time; ms = milliseconds; SD = Standard deviation; p = Significance probability; df = degree freedom

This study was conducted with 46 children (34 males and 12 females), aged 4 and 8 years old, 23 of whom were diagnosed with phonological disorder with involvement in the stops class (G1) and 23 with typical speech development (G2).

As shown in Table 1, T-Test showed a statistically significant difference between groups of children for the percentage of errors and correctness, as well as for the reaction time related to the correctness (all with $p<0.05$). Particularly, typical children had a higher mean of correctness (90.3%) than children with PD (81.5%) and a shorter reaction time for correctness (difference of 233 ms).

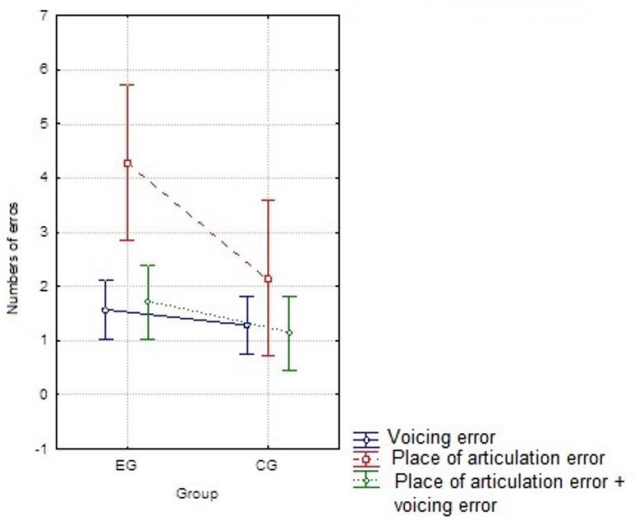
For data referring to the error pattern shown in Table 2, the repeated measures ANOVA showed a significant effect for group ($F(1.12,)=8.32$, $p=0.01$) and for the error pattern ($F(2.24)=10.33$, $p<0.01$), but there was no significant effect for the interaction between group and error pattern ($F(2.24)=2.42$, $p=0.10$). Again, children with PD had a greater number of errors compared to typical children.

Regarding the error pattern, Tukey's Post Hoc test showed that errors of perceptual identification involving the place of articulation were superior to the voicing errors and errors involving voicing and place of articulation for both groups, as shown in Figure 1 ($p <0.01$).

Table 2. Accuracy regarding error pattern to the control (G1) and experimental (G2) groups

Error pattern %	G1-Mean	G2-Mean
Place of articulation	15.60%	35.71%
Voicing	12.31%	12.31%
Place+Voicing	10.40%	13.60%
Total	38.31%	61.61%

Caption: G1 = Control group; G2 = Experimental group



Caption: Error pattern between EG and CG. EG = Experimental group; CG = Control group

Figure 1. Error pattern between groups

DISCUSSION

This study aimed to compare the auditory-perceptual performance of children with and without phonological disorder (PD) in the identification task of contrasts between stops phonemes. It was hypothesized that the auditory-perceptual performance of children with PD would be characterized by worse accuracy and longer reaction time.

In relation to the participants, in terms of speech perception, the literature reports that age influences perceptual performance to acquire the phonology of a language, the child must not only learn to discriminate the sound patterns of his/her language, but also consistently organize these sound patterns into their appropriate phonic categories. This ability is referred to as phonic identification[14], there is a discrepancy in the literature regarding the age at which perceptual speech ability is stabilized, ranging from 6 to 12 years[15]. There is no evidence that sex influences the perceptual performance. Thus, it is noted that from the age group evaluated in this study (4 to 8 years) the perceptual speech ability of the investigated group is still in development.

Regarding the auditory-perceptual accuracy, results showed a statistically significant difference between the groups of children, both for the percentage of errors and the percentage of correctness, in which children with PD had worse accuracy compared to the control group, fully confirming the first hypothesis.

Existing studies[10-12,14-18] have also confirmed that children with PD have difficulties in the accuracy of speech perception, suggesting that perceptual difficulties could interfere with phonological representation, reinforcing that, perceptual speech problems could precede or interact with production disorders.

Particularly, a recent study[10] investigated the general accuracy of speech perception in children speakers of English and Australian, in a lexical and phonic judgment task, and the results showed a significantly lower auditory-perceptual performance of children with PD. Another study, on the other

hand, investigated speech perception in children with apraxia of speech and with PD, through tasks of non-verbal and verbal auditory discrimination, word rhyme and categorical classification. It was hypothesized that the nature of production disorders would be correlated with greater/lesser perceptual difficulty. As a result, a low perceptual performance was observed for both groups, thus suggesting that production problems would be associated with alterations in the perception level, thus corroborating the hypothesis proposed by these authors[18].

Thus, the result found in this study may be one more evidence that children with phonological disorders may also have a speech perception disorder, which could be related to their own difficulty in production. Thus, the children in this study had both problems in the stops production and in the stops perception.

Regarding the reaction time, results obtained showed that children with phonological disorders show a more laborious reaction time for the correctness when compared to the control group; however, for the reaction time involving errors, there was no statistical difference between the groups, partially confirming our hypothesis.

The fact that the group of children with PD had longer reaction time for the correctness than the group of typical children, may show greater demand for processing by children with PD, thus reflecting the perceptual difficulty shown by this group, such as verified in a previous study[7].

However, the reaction time of errors demanded longer processing time for both groups, a fact already described in other studies conducted with typical children[11], which the response time of the errors is significantly higher than the response time of the correctness, suggesting that the stops contrasts that showed errors in the identification task impose greater auditory-perceptual difficulty (or greater auditory-perceptual similarity), consequently requiring more time for decision-making.

This auditory-perceptual similarity of the contrasts that showed errors similarly affected both groups in this study, since they did not have any statistical difference between them. Therefore, it is suggested that although children with PD have lower auditory-perceptual accuracy (higher percentage of errors), the processing time for decision-making is similar for both groups. In other words, the difficulty imposed for detecting a contrast with great perceptual similarity was the same for both groups, reflected in the non-differentiation of reaction times of the errors.

Finally, regarding the error pattern, there was a difference between groups. Once again, children with PD had a higher frequency of errors compared to the group of typical children, agreeing with results from previous studies, which described a worse perceptual performance of children with PD[10-12,14-18].

In both groups, errors involving the place of articulation were the most frequent, corroborating previous studies in which they showed similarities for characteristics of the errors shown between the group of children with PD and without speech disorders[10].

A possible explanation for similarities of the error pattern between groups, in which errors involving the place of articulation were superior to the voicing errors and errors involving voicing and place of articulation could be justified regarding the acoustic cues that mark the place of articulation are less robust, thus interfering in the identification of contrasts between stops[14,19,20].

In view that the groups of children analyzed in this study are part of the same language, both are exposed to the same acoustic phenomena, which would explain the similarity found for this topic.

Although the degree of severity of PD in the children's perceptual-auditory performance was not considered as interference, the results of this study show important clinical implications for the assessment and rehabilitation of children with PD; both regarding the perceptual accuracy and nature of error. Regarding accuracy, an average value for the group of children with PD is estimated at approximately 81.5% of correctness; while regarding the error pattern, the nature of error must be considered, that is, if it involves voicing contrast, place of articulation or place of articulation + voicing. Perceptual errors involving voicing, for example, could be considered more serious than perceptual errors in identifying stops involving only the place, since these errors were the least frequent.

In terms of contributions, it is believed that the findings of this study may (1) provide information regarding the perceptual performance of children with PD and (2) assist the speech-language setting in the analysis of perceptual performance of subjects with speech-language disorders. A limitation of this study is the fact that the severity of PD is not considered, not even the subtype of PD. Moreover, the auditory-perceptual investigation was restricted to the stops class.

Thus, it is suggested the auditory-perceptual investigation of other phonological classes of BP for future studies.

CONCLUSION

Children with phonological disorder showed worse auditory-perceptual accuracy for the stops class than children without disorders as well as a longer response time for correctness. This means that although children with PD have normal hearing thresholds, their perceptual performance seems to be impaired, showing the need for an assessment of this aspect. There was no difference between groups when comparing the error pattern. A possible outcome of this study would be to regard not only the correlation between production errors and speech perception errors, but also the influence of the severity of PD on perceptual performance.

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Author contributions

MFA was responsible for writing the project, selecting participants, tabulating and analyzing data, writing the manuscript, submitting and processing the article; EBMPC was responsible for tabling and analyzing the data; LMS was responsible for collecting, selecting participants; and; LCB was responsible for the project, study design, discussion of the findings and general supervision on the stages of execution and writing of the manuscript.