Original Article

Artigo Original

Children's auditory-perceptual performance in identifying phonological contrasts among stops

Desempenho perceptivo-auditivo de crianças na identificação de contrastes fonológicos entre as oclusivas

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Keywords

Auditory perception
Evaluation
Speech
Phonetics
Child

ABSTRACT

Purpose: To verify children's auditory-perceptual performance regarding the identification of contrasts among stop; to identify which phonemes and contrasts provide greater or lesser perceptual difficulty; and to verify age-related influence in auditory-perceptual accuracy. **Methods:** Information regarding the auditory-perceptual performance of 59 children (30 male and 29 female) in a task of identification of occlusive consonants in Brazilian Portuguese were selected from a database. The task consisted on the presentation of acoustic stimuli by headphones, and the choice of the picture corresponding to the word presented between two pictures displayed on the computer screen. The time of stimulus presentation and the reaction time were automatically computed by the PERCEVAL software. **Results:** It was found an 85% auditory-perceptual accuracy and a positive correlation with age. The reaction time for errors was significantly higher than the reaction time for correct responses. According to the confusion matrix, perceptual difficulty of contrasts varied: voicing cues are more salient than articulation cues. For the variable place of articulation of occlusive consonants, it was observed an auditory-perceptual asymmetry, in which the phonetic distance plays a key role in perceptual salience. **Conclusion:** The auditory-perceptual ability regarding the identification of stop contrasts is still not stabilized in the age range studied. The auditory-perceptual mastery of occlusive contrasts occurs gradually and, within this class, there seems to be a hierarchy in mastery.

Descritores

Percepção auditiva
Avaliação
Fala
Fonética
Criança

RESUMO

Objetivo: Investigar o desempenho perceptivo-auditivo de crianças no tocante à identificação de contrastes entre as oclusivas; identificar quais fonemas e contrastes oclusivos apresentam maior ou menor grau de dificuldade de identificação; e verificar se a idade influencia a acurácia perceptivo-auditiva. **Métodos:** Foram selecionadas, de um banco de dados, informações referentes ao desempenho perceptivo-auditivo de 59 crianças (30 do gênero masculino e 29 do gênero feminino) em uma tarefa de identificação da classe das consoantes oclusivas do Português Brasileiro. A tarefa consistiu na apresentação do estímulo acústico, por meio de fones de ouvido, e na escolha da gravura correspondente à palavra apresentada, dentre duas possibilidades de gravuras dispostas na tela do computador. O tempo de apresentação do estímulo e o tempo de reação das crianças foram computados automaticamente pelo *software* PERCEVAL. **Resultados:** Observou-se uma acurácia perceptivo-auditiva de 85% e uma correlação positiva com a idade. O tempo de resposta dos erros foi superior ao tempo de resposta dos acertos. De acordo com a matriz de confusão, houve contrastes de maior e menor dificuldade: pistas que marcam o vozeamento são mais robustas do que as pistas que marcam o ponto de articulação. Considerando apenas o ponto de articulação das consoantes oclusivas, observou-se uma assimetria perceptivo-auditiva, em que a distância fonética desempenha um papel fundamental na saliência perceptivo-auditiva. **Conclusão:** A habilidade perceptivo-auditiva no tocante à identificação de contrastes oclusivos ainda não está estabilizada na faixa etária estudada. O domínio perceptivo-auditivo dos contrastes oclusivos se dá de forma gradativa e, ainda, no interior dessa classe, parece haver uma hierarquia no domínio perceptivo-auditivo.

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Received: 8/22/2011

Accepted: 7/12/2012

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Conflict of interests: None

INTRODUCTION

To effectively acquire the phonological contrast of language, children need to develop, simultaneously, two fundamental skills: production and perception of the phonetic and phonological features that make segments similar or different[1].

When it comes to phonological contrasts, literature provides a wide array of studies that tackle their description, involving both typical and atypical acquisition[2-4]. However, a detailed description is not available regarding auditory-perceptual acquisition of phonological contrasts.

Especially in the Speech-Language Pathology field, previous researches dealing with such a subject focus primarily on speech perception in hearing-impaired children, using cochlear implant (CI) and/or hearing aids[5-8]. Nevertheless, there are few studies in national literature investigating auditory-perceptual performance and phonological contrasts in children with typical and atypical language development, concerning their auditory skills to identify and discriminate[9-13].

In international literature, researches that investigate the auditory-perceptual performance in adults and children with typical language development have indicated a substantial difference in their skill to identify and discriminate phonological contrasts[14-21]. In general, children show significantly higher (more accurate) auditory-perceptual performance when compared to adults in the skill to identify and discriminate language phonological contrasts, mainly in phonetic detail in speech perception[14-16,19-21].

Furthermore, data from researches on speech perception among children have described that accuracy to discriminate phonological contrasts in the mother tongue occurs between 2 and 7 years of age, which suggests that auditory-perceptual development takes place gradually[14-17]. It should be pointed out that 12-year old children still show differences in auditory--perceptual performance when compared to adults[18].

Yet, literature lacks a more detailed description of how auditory-perceptual acquisition occurs gradually. In other words, which phonological contrasts are first perceived remains unknown; which categories of sounds may favor such perception, and also, within the same category of sounds, which contrasts among the segments are likely to favor perception.

Thus, the present study had the aim to investigate auditory--perceptual performance of preschool children regarding the identification of phonological contrasts among stop consonants present in the Brazilian Portuguese (BP).

Specifically, the objectives were: to verify children's auditory-perceptual performance using an identification task of phonological contrast involving all stop consonants in BP; to identify which phonemes and occlusive contrasts show greater or lesser difficulty in auditory-perceptual identification; and to check whether age is correlated to auditory-perceptual accuracy.

We believe that the data obtained herein may lead to scientific gains, e.g., contributing to an understanding of speech perception acquisition and development in children with typical language development; providing further information on auditory perception of phonological contrasts of stop consonants in BP and contributing to the practice of auditory rehabilitation with hearing-impaired children, using hearing aid or CI, when it comes to speech sound perception.

METHODS

Sample

After approval of the Research Ethics Committee of the Universidade Estadual Paulista "Júlio de Mesquita Filho" (UNESP), Campus of Marília, protocol number 132/2010, we selected, from the GPEL database (*Grupo de Pesquisa Estudos sobre a Linguagem* – Research Group Studies on Language), data related to auditory-perceptual performance of 59 children, being 30 males and 29 females, with a mean age of 63 months (±6.18), regarding an auditory-perceptual task of identifying the stop consonants in the BP. The age bracket selected can be justified by the fact that the data bank is built from preschool children's linguistic data.

Children belonged to three distinct groups, namely Children I (20 children, with a mean age of 56.55 months, ±3.59), Children II A (19 children, with a mean age of 66.78 months, ±2.55) and Children II B (20 children, with a mean age of 68.25 months, ±3.43). After the comparison of ages among the three groups, by resorting to the t-test for independent samples, we grouped Children II A and Children II B (t-value=-1.50, df=37, p=0.14) and, on the other side, Children I (t-value=-10.02, df=37, p=0.00, in the comparison between Children I and Children II A; and t-value=-10.38, df=38, p=0.00, in the comparison between Children I and Children II B).

As sample inclusion criteria, we adopted data coming from children who had undergone a previous auditory triage. As sample exclusion criteria, we discarded data from children who showed language, neurological, and/or otological/auditory disorders, since such disorders might interfere with the auditory-perceptual performance.

Initially, we selected 72 children in the data bank. However, 13 children were excluded because they showed auditory alterations during the auditory screening.

The adults in charge of the children participating in the research read the items contained in the Informed Consent Form and provided written permission.

Material

The data related to auditory-perceptual performance of the data bank were obtained from an identification experiment involving the stop consonants, using the software PERCEVAL (Perception Evaluation Auditive & Visuelle)*.

To carry out the perception experiment, we selected high-frequency words in Portuguese, paroxytone two-syllable words, containing stressed stop consonants, preferably.

André C, Ghio A, Cavé C, Teston B. PERCEVAL: Perception evaluation auditive & visuelle v. 5.0.30 [Computer program]. Aix-en-Provence, 2009; 5.0.30.5.0.30 [Software]. Aix-en-Provence, 2009; 5.0.30.

The word selection was performed according to the following criteria: 1) the words should contrast the six stop consonants in the BP, so as to form minimal pairs; 2) the words should be represented by means of pictures; 3) the words should belong to the children's vocabulary and 4) the words should be in a list developed in a previous study[22].

Therefore, we gathered a total of 30 words, through combinatory analysis: 6 stop consonants x 5 = 30 words, being 15 contrastive pairs) (Chart 1).

Chart 1. Minimal pairs of words involving stop consonants in the perception experiment

Contrast among occlusive	Minimal pairs
/b/ x /t/	*berço-terço* (crib-rosary)
/b/ x /k/	*bola-cola* (ball-glue)
/g/ x /b/	*gola-bola* (collar-ball)
/b/ x /p/	*bote-pote* (dinghy-pot)
/b/ x /d/	*bucha-ducha* (sponge-douche)
/d/ x /g/	*danço-ganso* (I dance-goose)
/g/ x /t/	*guerra-terra* (war-earth)
/p/ x /g/	*pato-gato* (duck-cat)
/p/ x /d/	*pente-dente* (comb-tooth)
/p/ x /k/	*porta-corta* (door-it cuts)
/t/ x /d/	*tia-dia* (aunt-day)
/t/ x /p/	*torta-porta* (pie-door)
/k/ x /g/	*cola-gola* (glue-collar)
/k/ x /t/	*couro-touro* (leather-bull)
/d/ x /f/	*fada-faca* (fairy-knife)

As soon as the words that would be in the identification experiment were chosen, the recordings were performed with high-fidelity equipment, inside an acoustic cabin, with a typical adult speaker of BP. The adult was asked to produce the target words within a sentence, so as to avoid the ascending curve, which characterizes the production obtained when isolated words are repeated.

After the recordings, with the aid of the software PRAAT**, the minimal pairs were extracted from the sentence, yielding auditory inputs for the identification experiment.

While the audio files were being edited, we selected the pictures which corresponded to each word, from the public domain Google Image search engine (http://images.google.com.br/). With the software Paint, the images were cut and edited so as to follow a pattern, yielding visual inputs for the experiment.

By establishing the auditory and visual inputs that would integrate the identification experiment, we elaborated a script*** for the *software* PERCEVAL to execute.

Experimental procedure

The experimental procedure relied on an identification test (also known as two-alternative forced choice), which is composed of three distinct steps: recognition of the experiment words, training and testing.

The recognition test consisted of showing both visual and auditory inputs to children, in order to verify their awareness. After the children became familiar with the experiment inputs, we performed a survey, that is, a word recognition assessment. We adopted an 80% threshold of correct answers to conduct children to the training step and, eventually, to the auditory-perceptual test itself.

The training step is performed automatically by the software, aiming at ensure that the task is understood by the participants. This step consists of the identification task, but the obtained results are not computed by the software. The experiment stimuli are randomized and ten stimuli are selected. The next step is the training test.

For the identification task, the children were laid comfortably in front of the computer (containing the software PERCEVAL) with headphones Koss® attached to their ears, inside an acoustic cabin available in the school. The children, individually, heard (with binaural presentation and 50 dB SPL intensity) one of the minimal pair words. By pressing a previously assigned key, they were supposed to decide and indicate the corresponding picture, between two choices of pictures shown in the computer screen. For example, the children were auditorily introduced to the word "pote" (pot) and, subsequently, pictures corresponding to the words "pote" e "bote" (dinghy) were displayed in the computer screen. The participants had to decide and indicate which picture corresponded to the auditory stimulus introduced.

Both the appearance time length of the visual and auditory stimuli and the answer time span were controlled and measured automatically by the software PERCEVAL.

The experiment overall duration was approximately 15 minutes per children.

Analysis criteria

The following criteria were used for the analysis: auditory-perceptual accuracy (percentage of incorrect responses, correct responses and non-responses); reaction time of correct and incorrect responses; ability to identify contrasts among the stop consonants.

The following tests were used in the statistical analysis: t-test for dependent samples when comparing reaction times of errors and correct answers; Wilcoxon test, when comparing perceptual accuracy among children of Children I e II; and Spearman Linear Correlation Coefficient, when comparing the variables: age and auditory-perceptual accuracy.

Correlation measures the relation between two or more

** Boersman P, Weenink D. Praat: doing phonetics by computer (Version 5.0.30) Available from: http://www.praat.org/ [cited 2009 Nov 10]).

*** The script for the auditory-perceptual identification experiment may be provided by the first author through the following email: berti.larissa@gmail.com.

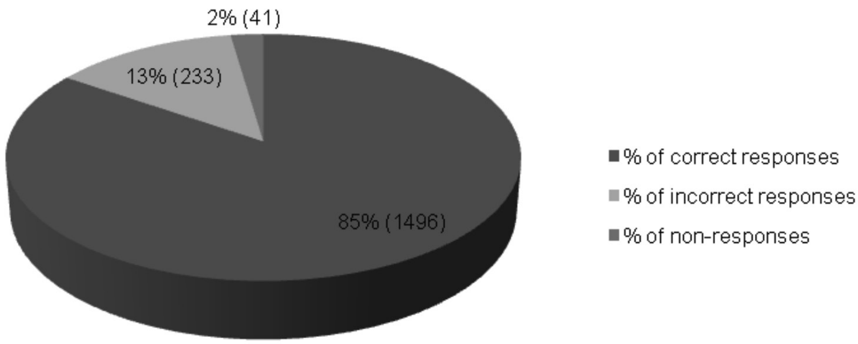


Figure 1. Children's auditory-perceptual accuracy regarding stop consonants identification

variables. The correlation coefficicient varies from -1.00 to +1.00. The -1.00 value represents a perfect negative correlation, whereas a +1.00 value represents a perfect positive correlation. A 0.00 value represents a lack of correlation.

We established a significance level of α<0.05 and the confidence interval was 95%.

To analyze the identification ability in contrasting the stop consonants, we used the confusion matrix[23] to quantitatively and qualitatively catalog the perceptual errors made by children. This type of analysis enables us to spot the most and least difficult contrasts in the identification tasks, as well as the most recurrent mistake patterns.

RESULTS

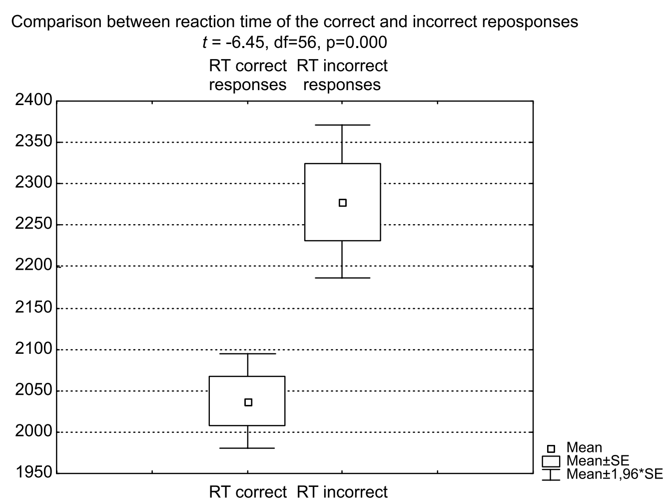
The results are shown according to the goals that guided the present research.

The first goal was to verify children's auditory-perceptual performance, through the identification task of phonological contrast involving all the stop consonants in the BP. Among the 1,770 stimuli appearances (30 stimuli x 59 children = 1,770 tokens), we calculated the auditory-perceptual accuracy considering the number of correct answers, errors and non-answers of each child. Figure 1 shows the obtained results.

Figure 1 demonstrates that children identified correctly 85% of the stimuli involving the contrast among stop consonants. Also, 13% of incorrect responses and 2% of non-responses.

In an attempt to verify if the answers in the identification task could have occurred by chance, that is, if children would randomly choose one of the alternatives, both the reaction time of errors and correct answers were considered and compared (Figure 2).

The mean reaction time of errors (2,278.10 ms; ±355.95) was significantly higher (t=-6.45, p=0.00) when compared



Note: RT = reaction time

Figure 2. Comparison between reaction time of errors and correct answers in the identification task

Table 1. Confusion matrix concerning the identification task of occlusive contrasts

Stimulus introduced	Answer							
	/p/	/b/	/t/	/d/	/k/	/g/	NA	Total
/p/	230	7	33	0	9	1	15	295
/b/	11	275	1	1	1	0	6	295
/t/	12	17	253	3	0	3	7	295
/d/	12	15	26	218	3	13	9	295
/k/	6	0	13	0	256	18	1	295
/g/	2	8	3	13	2	264	3	295
Total	273	322	329	235	271	299	41	1770

Note: NA = non-answer

to the mean reaction time of correct answers (2,037.59 ms; ±221.34), indicating that, indeed, occlusive contrasts that led to errors in the identification task entail higher auditory-perceptual difficulty. Consequently, more time is demanded to make decisions in terms of psycholinguistic processing.

The result analysis focused on the second goal – identifying which contrast(s) show(s) higher or lower degree of children's auditory-perceptual identification difficulty. The confusion matrix summarizes the most recurrent mistake patterns (Table 1).

According to the confusion matrix, this is the auditory--perceptual performance in relation to the identification of stop consonants, in descending order, in terms of the number of correct answers: /b/ (93.2% - 275/295) > /g/ (89.5% - 264/295) > /k/ (86.8% - 256/295) > /t/ (85.8% - 253/295) > /p/ (78% - 230/295) > /d/ (73.9% - 218/295).

Furthermore, taking into account the confusion matrix, the identification errors of the stop consonants were grouped into three categories: errors in the place of articulation, voicing errors and errors involving the combination of place of articulation and voicing.

It is noteworthy the fact that most errors may be grouped in the place of articulation category (52.78% - 123/233), followed by errors that combine voicing and place of articulation (28.75% - 67/233) and, lastly, errors involving voicing (18.45% - 43/233).

In the category of errors involving the place of articulation, the contrast between stop consonants – labial and dental – prevailed (50.40% - 62/123), followed by the contrast among stop consonants – dental and velar (30.89% - 38/123) and, then, the contrast among stop consonants – labial and velar (18.69% - 23/123).

To answer the third goal, that is, verifying if children's age could be correlated with auditory-perceptual accuracy, two analyses were conducted.

The first analysis consisted of comparing auditory-perceptual accuracy (regarding correct answers) between the two groups: Children I (children with a mean age of 56.55 months) and Children II (children with a mean age of 67.53 months). The Wilcoxon non-parametric test was used. The results proved that older children, those from the group Children II showed improved auditory-perceptual accuracy when compared to younger children's accuracy (Z=2.31, p=0.02). The second analysis consisted of the comparison between two variables – age and auditory-perceptual accuracy, by resorting to Spearman Linear Coefficient. Age was seen to correlate positively with auditory-perceptual accuracy (r=0.37, p=0.03), which means that as children grow older, their performance in the identification test tends to improve.

In sum, the results obtained in the present study suggest that auditory-perceptual mastery of the phonological contrasts involving stop consonants occurs gradually. Within this class, there seems to be a hierarchy in the auditory-perceptual domain.

DISCUSSION

Concerning children's auditory performance, we found that 4-year olds and 5-year olds still do not show a proper mastery of this skill. They showed a high percentage of correct answers in the identification task, though. These data corroborate previous studies[14-16,19-21], which state that auditory-perceptual accuracy for mother tongue is extended up to 7 years of age[16-17].

We should highlight the low percentage of non-answers, which suggests that the task required during the identification experiment was understood by the children, implying that the task was suitable for the age bracket.

When it comes to the errors made by children, there was concern whether the number of errors would be influenced by chance. Then, we considered the reaction time of errors and correct answers. We observed that the reaction time of errors was significantly higher than that of the correct answers. The results indicate that occlusive contrasts that led to errors in the identification task entail higher auditory-perceptual difficulty (or higher auditory-perceptual similarity). Consequently, more time is needed for decision making, in terms of psycholinguistic processing.

Concerning the identification of which phonemes and occlusive contrasts show higher or lower degree of children's auditory-perceptual identification difficulty, there was difference in performance among phonemes (individually) and the contrasts involving them.

Specifically, by analyzing the most recurrent mistake patterns in function of places of articulation of the stop consonants, voicing and the combination of places of articulation and voicing, we found a great deal of errors involving the places of articulation, followed by errors that combined voicing and the places of articulation and, lastly, errors involving voicing.

These results are in accordance with previous studies findings[23-24]. In the two referred classic studies, the researchers observed that voicing cues are more salient, perceptually, than the place of articulation cues.

In the category of errors involving the place of articulation, there was not a similar performance: errors involving the contrast among labial x dental prevailed, followed by errors between dental x velar and, lastly, errors involving the contrast between labial x velar.

By gathering studies that investigated the auditory-perceptual ability (both to identify and to discriminate) regarding the place of articulation, there is no consensus in the literature about auditory-perceptual salience of the stop consonant place of articulation in the prevocalic position.

A pioneer study in this field[23] states that among the stop consonant place of articulation, the coronal consonants show more auditory-perceptual salience. Nevertheless, there are no substantial differences among the labial and velar stop consonants in terms of auditory-perceptual salience. Differently, authors of another study[24] found that both the labial and coronal stop consonants show, similarly, high auditory-perceptual salience, whereas velar stop consonants show low salience, which corroborates the results obtained in the present study.

It was found[25] that, in general, labial consonants are typically more salient, while velar consonants are described as less salient consonants.

In relation to the results obtained in the identification of contrast across the stop consonant place of articulation, the phonetic distance among the phonemes seems to play an important role. The higher the phonetic distance, the lower the auditory-perceptual similarity. Thus, the performance in the auditory-perceptual task is better.

Finally, the children's age showed to be an important factor in the auditory-perceptual performance. Younger children showed worse accuracy when compared to older children. As children grow older, accuracy tends to be improved. Such results corroborate those found in studies mentioned earlier(14-17,19-21), which suggest that auditory-perceptual acquisition of phonological contrasts occurs gradually.

Important findings of the present study may be considered in the Speech Pathology field. The first one refers to the importance of taking into account the children's age in the moment of the auditory-perceptual evaluation when it comes to the identification task. Around 5 years of age, perception does not seem to be thoroughly stabilized.

The second finding refers to the importance of considering the auditory-perceptual hierarchy in the stop consonants class. For example, difficulty in identifying a contrast of voicing among the stop consonants has a different status when compared to difficulty in identifying a contrast involving the place of articulation.

In the end, such findings may still be useful to enhance speech processing algorithms for cochlear implants.

CONCLUSION

Our results show that the auditory-perceptual skill related to the identification of occlusive contrasts fails to be stable in the age bracket studied. Also, the ability occurs gradually – the identification of occlusive contrasts differs from the identification of similar contrasts. There are occlusive contrasts that entail higher or lower difficulty, suggesting a auditory-perceptual hierarchy.

Cues related to the stop consonant class seem to be more salient than those related to the place of articulation. Additionally, by considering solely the stop consonant place of articulation, auditory-perceptual asymmetry is observed. The phonetic distance seems to play an important role in the auditory-perceptual salience. In other words, the higher the phonetic distance, the lower the auditory-perceptual similarity, enabling, then, the identification of contrast among stops.

The children's age was positively correlated with auditory--perceptual accuracy, suggesting that as they grow older, there is improvement in the ability of identifying the occlusive contrasts.

The present study should continue so as to investigate the identification of the phonological contrasts, involving other sound classes. It should also expand the population, including other age brackets.

ACKNOWLEDGEMENT

We would like to thank the São Paulo Research Foundation (Fundação de Amparo à Pesquisa do Estado de São Paulo – FAPESP), for the support. Number 06/61816-4; 2010/00757-6.

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