PRODUCTION AND DISCRIMINATION OF VOICING CONTRAST OF STOPS IN CASES OF PHONOLOGICAL DISORDER

Produção e discriminação do contraste de sonoridade das plosivas nos casos de desvio fonológico

Roberta Michelon Melo[(1)], Helena Bolli Mota[(1)], Carolina Lisbôa Mezzomo[(1)], Brunah de Castro Brasil[(1)]

ABSTRACT

The stops voicing contrast represents a complex acoustic and articulatory coordination, frequently impaired in cases of speech disorders. Therefore, one believes that the researchers should strive to understand the factors that influence in the stabilization of that contrast. So, the purpose of this research was correlating the production data and the performance in a perception test of the feature [±voice] in speech disordered children. Thereunto, five speech-disordered boys, that presented difficulties in the production of voiced stops and other difficulties, were evaluated. Through the pairs of words introduced in carrier phrases, one observed the occurrence of positive voice onset time production during the [+voice] stops production and the duration pattern of the vowels adjacent to the voiced and devoiced stops. The authors elaborated a Perception of Stops Voicing Test to evaluate the subjects' performance regarding to the perception. The test has 12 pairs of words, in which the difference is only the contrast [±voice] and it's represented by pictures. Through a descriptive analysis, no direct relation between difficulties of stops voicing contrast production and speech perception of this sounds was verified, both on the observation of pre-voicing production, and on the observation of vowel duration pattern production. Nevertheless, one emphasizes that the use of perception evaluation and acoustical analysis in cases of speech disorder shouldn't be ignored by the speech pathologists, because those instruments can give important information to a good therapeutic progress.

KEYWORDS: Child; Speech; Speech Disorders; Speech Acoustics; Sound Spectrography; Speech Perception

INTRODUCTION

In Brazilian Portuguese (BP), the class of stops is represented by six segments - /p/, /b/, /t/, /d/, /k/ and /g/. For the production of those obstruents two essential articulation moments are required, the first refers to a complete obstruction of the air passage by the phonoarticulatory organs, and the second, to a sudden release of that air current. Those articulatory gestures can be identified, via spectrogram, by an interval of silence followed by a transient noise, known as *burst* [1].

The distinction between voiceless and voiced and stops is acoustically marked by the absence or presence of absence or presence of pre-voicing or voicing concomitant to *burst*, i.e., by a positive, negative or zero *Voice Onset Time* (VOT) [1-3]. In addition to VOT, other acoustic signals are also mentioned as being responsible for establishing the voicing contrast, among them, the length of the vowel adjacent to stop [2,4,5], to *burst* amplitude[1,5,6] and length of the occlusion preceding to burst [4,5,7].

The voicing contrast of stops involves, therefore, a complex temporal-spatial coordination of oral and laryngeal gestures. Such articulatory and acoustic refinement is a hard task for some children with phonological disorders [3,5] and, in addition to impairing

(1) Programa de Pós-Graduação em Distúrbios da Comunicação Humana da Universidade Federal de Santa Maria – UFSM, Santa Maria, RS, Brasil.

Scholarship agency: FAPERGS/CAPES (Doctorate Scholarship).

Conflict of interest: non-existent

speech intelligibility and perception of the listener, the instability of the feature [+ voice] in phonological therapy seems to persist for a long period [1].

In relation to the perception, it is a consensus that during the early stages of language acquisition, perception precedes production. Before the first words or phonemes begin to be produced, the child perceives and understands a lot more speech than he/she actually produces. Thus, the development of speech is closely related to auditory perception [8].

The auditory perception, in turn, can be subdivided into several components such as: detection, sound sensation, discrimination, location, recognition, understanding, attention and memory [2].

Some researches focused on the perception of the listener front some distinct sound acoustic characteristics from those ones observed in adult speech, whether through speech data - in development - in young children [9], or in children already diagnosed with phonological disorders [3]. In contrast, other studies [1,2,10,11] carried out an investigation specifically about the auditory discrimination in children with difficulties in establishing the voicing contrast of stops. Most of the results presented above suggest an adequate perception in those cases in which children appear to adequately distinguish the contrast of sounds that they do not produce properly. Some of these authors also reported that difficulties in the perception and in the production levels can impair the progression of the speech therapy [10].

However, we believe that there are still many gaps in the understanding of this relationship. The persistence of a difficulty in stabilizing the contrast [+ voice] is a recurring situation that speech therapists have encountered. For that reason, we believe that efforts should be made to better understand the factors that influence the stabilization of this contrast. With this desire, this research reports an instrumental method of analysis of speech production (acoustic analysis), connecting it to data discrimination of this contrast.

In face of what was mentioned, the aim of this study is to correlate production (VOT and vowel duration adjacent to stop) and discrimination of voicing contrast of stops in children with phonological disorders.

PRESENTATION OF THE CLINIC CASE

This study was approved by the Research Ethics Committee of the institution of origin which was developed under the number 23081.008886/2009-29. It was carried out in a school clinic associated to a higher education institution and to the Unified Health System (SUS), and also to two schools of public schools in the same city.

Study sample

We considered the speech data of five boys aged five years and four months to seven years and nine months (average age = seven years, standard deviation = 11.8 months), with phonological disorder and difficulty in the production of voiced stops, among other speech difficulties.

In order to include those children in the research, it was necessary to adopt the following criteria: have permission to participate in the research through the Consent Term, be aged between four and eight years and eleven months, had not received previous therapy phonological; be native speaker of BP, no history of bilingualism and having a diagnosis of phonological disorders, percentage of correct production of voiced stops up to 39% (failing to produce a perceptible contrast between voiced and voiceless stops in relation to a percentage greater than or equal to 40%), whereas the voiceless stops should be acquired in phonological system. This criterion was adopted according to the resolution of another study [12], which suggests that a phoneme is considered to be acquired when their occurrence is from 80% to 100%; partially acquired when the instance is from 40% to 79%, and not acquired when its occurrence is equal to or less than 39%.

In relation to the exclusion criteria were considered: the presence of vocal, auditory, language, evident neurological damage in the cognitive, psychological and / or emotional aspects, and changes in the orofacial organs that were related to the phonological system.

For sample selection it was performed speech, voice, language and hearing screening, consisting of: (a) initial interview conducted with parents and/or guardians, (b) assessment of the stomatognathic system, with emphasis on observation of the aspect, posture, muscle tension and mobility of orofacial organs (tongue, lips, cheeks, dental occlusion and the aspect of the soft palate and hard palate) and functions (breathing, speech articulation, chewing and swallowing), (c) assessment of language, speech and voice, through spontaneous speech elicited through a logical sequence of four facts. And yet, a hearing screening was performed with the testing of hearing thresholds by air from 500 to 4000 Hz, tested at 20 dB HL (scan mode). The audiometer was used *Interacoustics Screening Audiometer AS208*, properly calibrated and respecting the care of the ambient noise. Finally, it was carried out the Phonological Assessment of Children (PAC) [13].

Acoustic analysis

To obtain the data submitted to acoustic analysis, we created a list of words of the same linguistic context (two syllables, penultimate stress and in the context of the vowel / a /), containing the contrast [+ voice] of the six stop of BP (*['papa], ['baba], ['tata], ['dada], ['kaka] and ['gaga]*). The words were inserted in the carrier phrase (*"Fala _____ de novo"*).

Stimuli containing the carrier phrase were arbitrarily presented by using headphones (*Sennheiser HD280 PRO*) and, children were asked to repeat the entire heard phrase according to the usual vocal quality they were used to. Thus, a total of 180 productions were analyzed (two recordings x three repetitions x six stops x five children = 180 productions).

The instruments used for data recording were: an acoustics cabin, an omnidirectional microphone (*brand Behringer EMC8000*), placed on a pedestal, about four inches from the mouth of the individuals; and an external sound card *(brand M-AUDIO, model FW 410*) connected to a laptop computer. The recordings were made directly in the MATLAB software V7.1 SP3 (*Simulink Signal Processing Toolbox V6.4*) in Wave file and in high resolution (24 bits and 96 kHz).

Then, the speech registers were analyzed in a processing audio software named *Praat* - version 5.1.29 (*available at www.praat.org*), with a sampling rate of 96 kHz and 16 bits. By means of spectroscopy it aimed at prevoicing production, i.e., the measure of VOT (if negative), during the production of stops [+ voice], and measured the length of vowels in the context of stop [+ voice] versus [-voice].

The percentage of production of prevoicing was estimated from the number of times that the preceding voicing bar to *burst* was observed, divided by the total number of stops [+ voice] that were produced, multiplied by 100.

To measure the length of the vowel in milliseconds (ms), we adopted the criterion of first and last regular cycle adjacent to stop to determine the limits of each vowel segment. After, we compared the first measure of length of the vowel in the context of stop [-voice] with the first measure of the length of the vowel in the context of stop [+ voice], and so on, among the other five repetitions of each target word. Thus, the length of the vowel was contrasted in the context of the length of the vowel[p] versus[b], [t] versus [d] and [k] *versus* [g]. This comparison was made to verify if the length of the vowel in the context of voiced stops was longer, as described in the literature [2,4,5]. Finally, we calculated the percentage of cases that this pattern occurred.

Stop Voicing Discrimination Test (SVDT)

For the investigation of the performance of the individuals in a contrast discrimination task [+ voice] of the six stop consonants of BP, it was elaborated the "Stop Voicing Discrimination Test (SVDT)", based on "Phoneme Discrimination Picture Test " [14], once the last one had few minimal pairs contrasting voiceless and voiced stops, focus of this study.

For preparation of the test, in a first moment, the three possible voicing contrasting of stops in the BP were included, i.e., /p/ *versus* /b/; /t/ *versus* /d/; /k/ *versus* /g/. Then, two minimum- pairs were selected for each position in the word, initial *onset* and medial *onset*. Thus, we obtained 12 pairs of words, including all stop phonemes and belonging to the vocabulary of the child (such as Figure 1).

Two word pairs, well known by children, were also selected, which served as a items of demonstration of the test, so that they could obtain a better understanding of the orders of it (as set out in Figure 1).

Demonstration items of TDSP	**1.** Show: Caminhão e Boneca **2.** Show: Faca e Pata
Stimulus of TDSP	**1.** Show: Pomba e Bomba **2.** Show: Pingo e Bingo **3.** Show: Sapão e Sapão** **4.** Show: Tope e Toby (name of dog) **5.** Show: Tênis e Denis (name of boy) **6.** Show: Tourada e Dourada **7.** Show: Gato e Gato** **8.** Show: Anta e Anda **9.** Show: Cola e Gola **10.** Show: Calo e Galo **11.** Show: Vaca e Vaca** **12.** Show: Leco (name of bear) e Lego

Figure 1 – Presentation protocol of Stop Voicing Discrimination Test (SVDT)

We chose to select words frequently presented in children vocabulary in the age group of children who participated in the study, and also words that were easily representable by means of figures. However, with respect to some selected word pairs, such criteria could not be truly followed, due to the immense difficulty of selecting minimal pair sin relation to the studied oppositions. That occurred in cases like: *tope x Toby (dog); tênis x Denis (boy); tourada x dourada; anta x anda; vaca x vaga; Leco (bear) x lego.*

Then, it was hired a professional of the visual arts for preparing the illustrations, which required a closer understanding of the drawing with the reality. Each minimum-pair was then represented by figures arranged in three columns, as the example displayed in Figure 2. If any researcher expresses interest in the complete instrument of this research, he/she may contact the authors of this work.

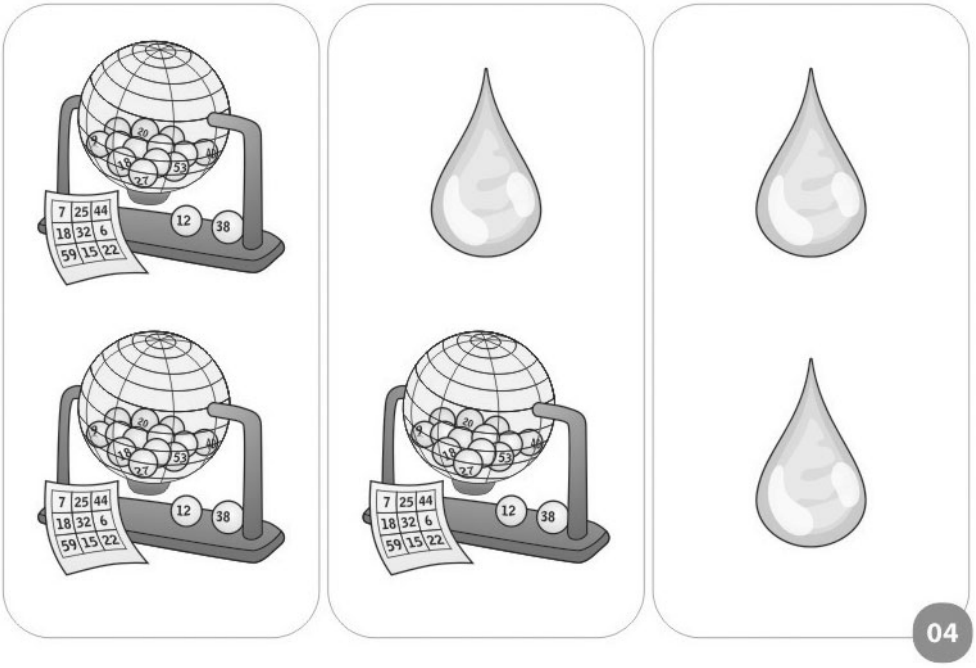

Figure 2 – Example of chart figure used in Stop Voicing Discrimination Test (SVDT) – P*ingo x Bingo*

The test was composed of 12 illustrated cards (Figure 2), a Protocol of Presentation (Figure 1) and a Protocol of Answers (Figure 3). Each card consisted of three columns, the first being released twice the figure that shows the first word, in the second, twice for the figure that shows the second word and, the third contained the figures that illustrate the first and second word simultaneously. The organization of the columns was not necessarily in that order, so that it was not induced a pattern response.

CONTRAST [±voice]		MINIMAL PAIRS		Answers		
				A	B	C
/p/ x /b/	*Initial Onset*	1.	Pomba x Bomba			
		2.	Pingo x Bingo			
	Medial Onset	3.	Sapão x Sapão**			
		4.	Tope x Toby (Dog)			
/t/ x /d/	*Initial Onset*	5.	Tênis x Denis (Boy)			
		6.	Tourada x Dourada			
	Medial Onset	7.	Gato x Gato**			
		8.	Anta x Anda			
/k/ x /g/	*Initial Onset*	9.	Cola x Gola			
		10.	Calo X Galo			
	Medial Onset	11.	Vaca x Vaca**			
		12.	Leco (Bear) x Lego			

Note: The squares highlighted in the columns of answers refer to the correct answers.

Figure 3 – Protocol of answers of Stop Voicing Discrimination Test (SVDT)

In relation to the procedure of the SVDT, initially, it was explained to children "what would be done" and "how it would be done." Then, first, the items of demonstration were presented and, after, the analyzed minimal pairs. The child listened through headphones the stimulation of the test, which was previously recorded by a female subject - *"mostre pingo e bingo"* and he/she should point to the corresponding column.

Nine orders of the test had two different words, and other three orders, two words were equal, denoted by two asterisks (**) in Protocol of Answers of the SVDT. This procedure was selected with the intention that the child paid attention to test stimuli and also that there was not a pattern of induced answers.

Despite the stimuli of the test have been provided by using headphones, the researcher should be very careful to not give the children language and/or visual clues, allowing, this way, that they have the guidance, unique and exclusively, of the auditory stimulus.

Regarding the score o0f the SVDT, it was added one point for each correct answer and zero for incorrect answers or for the ones that required the help of the examiner. Therefore, the total amount would be 12 points.

Data analysis

After cross-sectional collection, the production data and discrimination of stop phonemes were analyzed by means of a descriptive analysis.

RESULTS

For the prevoicing production of voiced stops, only one child in the sample presented a negative VOT during the production of stops. On the other hand, there was a greater use of other acoustic indication, length of the vowel adjacent to stop, among all children in the sample.

Regarding the performance in the SVDT, children in the study had mean score of 70%, with a median of 75%. With the percentage of correct answers on the test ranged from 33.33% to 91.67%.

Table 1 presents the results for all the variables of the study, per individual.

Table 1 – Presentation of variables of study by participant - percentage of prevoicing production; percentage of production of long vowel in the context of stop [+ voice] and percentage of correct answers in the Stop Voicing Discrimination Test (SVDT)

Participants	Variables						
	Prevoicing - /b/ -	Prevoicing - /d/ -	Prevoicing - /g/ -	Length of Vowel - /b/ -	Length of Vowel - /d/ -	Length of Vowel - /g/ -	Correct answers in the SVDT
C1	0/0	0/0	0/0	0/3	4/5	4/6	11/12
	0%	0%	0%	0%	80.00%	66.67%	91.67%
C2	3/6	4/6	2/6	5/6	5/5	4/6	7/12
	50.00%	66.67%	33.33%	83.33%	100.00%	66.67%	58.33%
C3	0/0	0/0	0/0	3/6	1/2	2/6	9/12
	0%	0%	0%	50.00%	50.00%	33.33%	75.00%
C4	0/0	0/0	0/0	3/6	3/6	4/5	4/12
	0%	0%	0%	50.00%	50.00%	80.00%	33.33%
C5	0/0	0/0	0/0	5/6	1/6	3/5	11/12
	0%	0%	0%	83.33%	16.67%	60.00%	91.67%

Legend 1: C – children (participants of study); SVDT – Stop Voicing Discrimination Test.

By comparing the percentage of prevoicing production and the percentage of correct answers in the SVDT of each child, it is not possible to show a positive relation between the perception and production of the feature [voice], once that it is possible to notice, according to the data, that the only child who showed signs of negative VOT production, who obtained 58.33% of accuracy on the test, i.e., a lower percentage of the one evidenced for some children in the sample that showed the absence of pre-voicing for all voiced stops.

When analyzed together, the percentage of production of long vowel in the context of stop [+ voice] and the result in the SVDT also give the impression of bringing evidence of a relation between production and perception in the studied sample. It is possible to affirm that once for some children the percentage of production of standard length expected for the vowels was higher than the percentage of correct answers in the discrimination test and, for others, the reverse is also verified.

Further, in order to observe if the minimal pairs of the SVDT influenced the performance of children in the test, it was counted for each pair, the minimum error for each pair in the sample. It was observed that the maximum number of errors per pair of three incorrect responses was for the pair *"tope x Toby"* and no incorrect answers for the pair *"tourada x dourada"* (Figure 4).

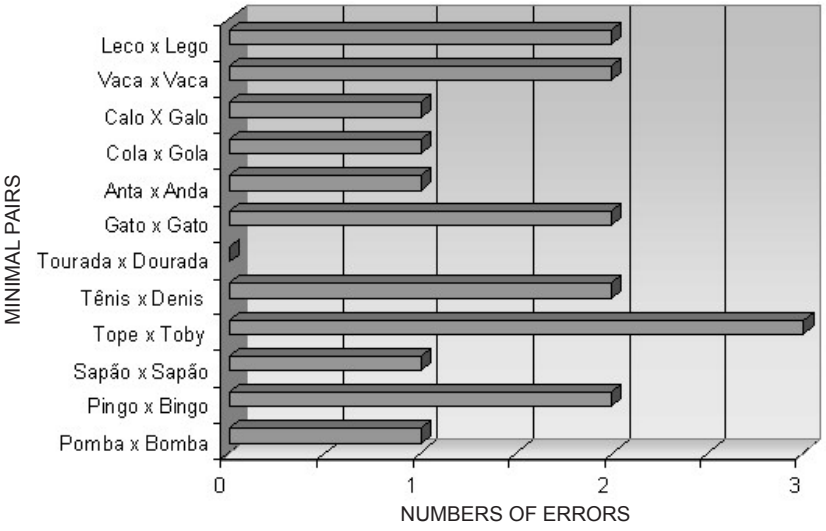

Figure 4 – Errors total, by minimal pairs, in the Stop Voicing Discrimination Test (SVDT)

DISCUSSION

The introduction of acoustic spectrography in data interpretation of children with phonological disorders, has increasingly established itself as a practical and necessary tool during the speech assessment [1-7,10,11,15-18]. The observation of attempts of correct production of sounds, verified via spectrogram and, which were not previously identified by auditory perceptual analysis, has already been reported and confirmed by many studies of the area [1,5,6,10,11,15-18].

A research [5] that also investigated the voicing contrast of the stop phones found that a group of children with speech and difficulty in stabilizing the feature [+ voice] did not distinguish acoustically the voiced x voiceless contrast. However, even though children with phonological disorders have not submitted to a differentiation of voicing through the investigated acoustic parameters (VOT, length of the vowel, length of the occlusion and burst amplitude), those ones showed a tendency to anchor on clues that are less robust during the attempt of implementing that contrast. In this case, taking the clue of length of the vowel adjacent to stop and of burst amplitude.

In the study, it was also observed that the production of a negative VOT for the stops [+ voice] appears to be a quite complex and rarely used acoustical clue by children who have not yet stabilized the voicing contrast sounding in his/her phonological system. That can be confirmed by the percentage of prevoicing, once only one of the children presented the production of voicing bar preceding to burst, confirming the requirement of a complex temporal coordination between glottal (vocal fold vibration) and supra-glottal (oral gestures) events, which was corroborated in another study [3].

In contrast, for the presence of longer vowels in the context of voiced stops, it was observed that despite not in all occurrences of the analyzed words, this acoustic clue was used in the speech of all assessed children, agreeing with the research that was mentioned above [5].

The previously discussed fact also confirms the existence of redundant and secondary clues in relation to the identification of the stop phones [2,3,6], so that even when using some distinct acoustic parameters among stops [+ voice], the auditory perceptual analysis that was carried out for the inclusion of the individuals in the research, identified less than 40% occurrence of voiced stops in the phonological system of the children. So, it is important to mention the presence of a more refined knowledge in the speech description, identified by the acoustic spectrography, then that information cannot be ignored. That fact seems to be confirmed in another theoretical perspective through the covert contrast [15-19].

For the discrimination of voicing contrast, it was observed in this research that only one of the children had a low performance in the SVDT, with a percentage of less than 50% of correct answers.

This result differs from another study [20], which investigated the phonemic discrimination of all phonemes of BP, also in children with phonological disorders. Those authors also suggested a possible causal relation between an inability of auditory discrimination and phonological disorders that, however, did not apply to all cases they assessed. This relation was also mentioned by another author [8].

However, there seems to have an inconsistency in the literature regarding the association of deficits in the auditory production and discrimination. In another study [11], for example, it was verified no relation between perception and production of the voicing feature. Children with deviant speech presented a higher number of correct answers with reference to stop consonants; however, they produced more accurately fricative consonants.

Corroborating in some aspects to the referred study, this research also seems to show a direct relation between discrimination and production of the feature [+ voice], being that four of the five children presented favorable results in SVDT. However, only one of them showed vocal fold vibration when producing some voiced stops, and all assessed children employed the acoustic clue of length of the vowel, even if not in 100% of cases.

A discrepancy between perceptual tasks and production of speech sounds has also been described in the literature for children with articulation disorders [21] and phonological disorders [1,10,11]. A theoretical model able to accommodate the differences between the levels of perception and production is the Two-Lexicon Model, this one suggests the existence of a lexicon input (used for words recognition) and a lexicon output (used for the words production). A fail in the connection between these two lexicons result in deficits in one or another level [21].

Another study [19] highlights that there is a possible influence of other factors in perceptual performance, including: peculiarities of the language, pre-established cultural concepts, type of perceptual tasks, among others. Then, the auditory information, separately, would not be the only basis of the perceptual judgment of a sound.

Regarding the type of perceptual task, another author [16] highlights from her findings that children with phonological disorder showed a difficulty in

identifying contrasts from typical categorical stimuli, unlike the results of some assessed individuals in the study.

However, when faced with their own gradient stimulus (i.e., with the presence of covert contrast, denoting an knowledge in construction), their perception tends to be more pronounced and may be guiding these children for nonstandard (or secondary) acoustic-auditory clues, both in production levels, as in perception.

Although the data shown here have not evidenced a cause-effect relation between perception and production of voicing contrast, it is important to carry out some assessments of discrimination and inclusion of strategies that enable children with phonological disorders, establishing the connection between discrimination and phonemic aspects of speech production. Once, from the perception of the differences between their productions from the productions of an adult, the child starts the movement of abandoning the stable pattern in his/her speech to venture into new attempts. Therefore, this is a facilitator period, permitting the speech therapist to provide the ways and appropriate means to promote the approach to the standard language [17].

This fact may be reinforced by another study [22], which states that the presence of positive results in relation to the phonemic discrimination of specific sounds can promote a greater progression of therapy, giving important considerations for the selection of target sounds, as well as for the type of treatment to be adopted. Moreover, the insertion of a perceptive training concomitant to phonological therapy is capable to offer improvements in the phoneme discrimination, as in speech patterns [23].

With respect to the instrument that was used in this study, it was also investigated a possible influence of the minimal pairs of the SVDT at the performance of the assessed children.

It observed that the minimum-pair *"tope x Toby"* was the one that presented the most errors in the discrimination of stops [+ voice]. Consequently, it is possible to infer that the fact of agreeing with the child that the figure of the dog was referring to "Toby" has not been a good alternative to assess phonemic discrimination, due to lexical influences. However, the pair which showed no error in the test was *"tourada x dourada"*, words that we believe are not very common in the vocabulary of children.

Therefore, in order to break some difficulties during the selection of minimal pairs, like - words that are not frequent in the vocabulary of children and hardly representable by means of figures - it was decided to submit them before the SVDT, with the aim of evaluating, exclusively, the discrimination of the voicing contrast of stop phones, eliminating potential difficulties of the lexicon.

In order to contribute to further studies, it is suggested to increase the sample of this research, which was not possible because of the necessity of considering strict inclusion criteria. Besides, it is suggested the inclusion of other minimum-pair that could focus the voicing contrast of the other phones in the BP, such as fricatives and affricates, as well as the implementation of the SVDT to other samples, such as bilingual speakers, with language disorders, with dyspraxia, among others.

FINAL CONSIDERATIONS

The results presented here do not point to a direct relation between difficulty in producing of voicing contrast of stops and auditory discrimination of these segments, both in observing the production of negative VOT, as in the observation of the standard production of the length of the vowel.

Thus, in our sample, the difficulty at the stabilization of the production of the contrast [+ voice] does not seem to be related to a difficulty in a perceptual level, more specifically, at the level of phonemic discrimination of these sounds.

However, even though this relationship has not been found, it is noticed that the use of an assessment of phonemic discrimination, as well as performing an acoustic analysis in cases of phonological disorder, should not be ignored by speech therapists. The results of these assessments may point to the necessity of a therapeutic intervention in this part, and then indicate a greater phonological knowledge of some children with phonological disorders, which could contribute to a more immediate therapeutic success and, thus, contribute to a better prognosis.

ACKNOWLEDGMENTS

To the children and their parents by the availability of participation in research. To the Foundation for Research Support of the State of Rio Grande do Sul (FAPERGS) and the Coordination of Improvement of Higher Education Personnel (CAPES) for providing a PhD scholarship of the first author.

RESUMO

O contraste de sonoridade das plosivas representa uma complexa coordenação acústica e articulatória, muitas vezes prejudicada nos desvios fonológicos. Por esse motivo, acredita-se que esforços devem ser realizados no sentido de melhor entender os fatores que influenciam na estabilização desse contraste. Assim, o objetivo desta pesquisa foi correlacionar os dados de produção e o desempenho em um teste de discriminação do traço [±voz] em crianças com desvio fonológico. Para isso foram avaliados cinco meninos com desvio fonológico e dificuldade na produção das plosivas sonoras, entre outras dificuldades de fala. Por meio de pares de palavras inseridos em frase-veículo, observou-se a ocorrência de produção de *Voice Onset Time* positivo durante a produção de plosivas [+voz] e o padrão de duração das vogais adjacentes às plosivas surdas e sonoras. Elaborou-se um Teste de Discriminação de Sonoridade das Plosivas, a fim de se avaliar o desempenho dos sujeitos em relação à discriminação. O teste consiste de 12 pares de palavras, diferenciados apenas pelo contraste [±voz] e representados por figuras. Na análise descritiva, não se verificou uma relação direta entre dificuldade de produção do contraste de sonoridade das plosivas e discriminação auditiva desses segmentos, tanto na observação da produção de pré-sonoridade, quanto na observação da produção do padrão de duração das vogais. Mesmo assim, salienta-se que o emprego de uma avaliação de discriminação, bem como, de análise acústica nos casos de desvio fonológico, não devem ser desprezados pelos fonoaudiólogos, uma vez que esses instrumentos podem fornecer informações fundamentais para um bom progresso terapêutico.

DESCRITORES: Criança; Fala; Distúrbios da Fala; Acústica da fala; Espectrografia do Som; Discriminação da Fala

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Received on: March 10, 2013
Accepted on: May 15, 2013

Mailing address:
Roberta Michelon Melo
Serviço de Atendimento Fonoaudiológico - SAF
Rua Mal. Floriano Peixoto, 1751 - Centro
Santa Maria – RS – Brasil
CEP: 97015-372
E-mail: roberta_m_melo@hotmail.com