ESTABLISHMENT OF PHONOLOGICAL CONTRASTS AMONG FRICATIVES BY CHILDREN WITH A PHOLOGICAL DISORDER: ACOUSTIC CUES MANIPULATION

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▪ ABSTRACT: The present study focuses on the presence of covert contrasts in the speech of children with a phonological disorder. The hypothesis is that children with phonological disorders manipulate secondary acoustic cues in an attempt to distinguish the phonological contrasts. We used five audio recordings of the speech of five children with speech disorders, between four and five years of age, who showed the so-called "phonic substitution" involving the sound group of the fricatives. The data were edited and analyzed using the software PRAAT. A phonetic transcription of the first repetition of each child was performed by three evaluators, reaching a 66% agreement level. After the transcription, we carried out a contrastive phonological analysis of the production of the five children and, finally, an acoustic analysis of all the "substitutions", based on six parameters. We discovered the existence of covert contrasts in the productions auditorily regarded as homophones by the evaluators, representing a total of 54% of total substitutions identified through an impressionistic approach by the evaluators. Children with phonological disorders are seen to rely on secondary acoustic cues in an attempt to distinguish fricative phonemes. The data obtained in this study allow us to reflect on the importance of considering the phonetic detail within the phonological models.

▪ KEYWORDS: Phonological Acquisition. Phonetic. Phonological Disorder. Acoustic Analysis. Fricatives.

Introduction

Every language shows specific sets of phonological contrasts which provide informative aspects of the language system. Language contrasts are perceived and produced whenever certain perceptual and articulatory skills are mastered by learners.

The phonological contrast can be regarded as being equivalent to "musical chords" or to a "constellation of cues", as designated by Scobbie et al. (1996),

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resorting to several "notes" or "stars". The "notes" composing the chord (contrast) are known as acoustic cues. Such phonetic cues show varied interdependence and perceptual significance (SCOBBIE, 1998).

In detail, each phonological contrast is composed of a set of acoustic cues. Therefore, speakers of a given language are expected to be aware of which cues are relevant in their language and how to use them correctly, since the same cue might be present in different phonological contrasts (MUNSON et al., 2010).

As the same acoustic cue may compose different contrasts, it is necessary to master a type of hierarchical cues, that is, to ponder which of them are primary (fundamental to promote phonemic distinction) and which are secondary.

Let us see an example. As previously reported by Scobbie (1998), the Voice Over Time cue (VOT)[1] may be, at the same time, considered a primary cue in the establishment of voicing contrast among stop consonants and also a secondary cue in the establishment of the place of articulation among stop consonants.

Regarding phoneme acquisition, a child needs to master and organize primary and secondary cues so as to enable listeners to effectively perceive a certain contrast.

Although most seven-year-olds master the target phonological system, some of them are seen to differ from their peers regarding awareness of phonological rules and phonetic repertoire, without organic causes that justify developmental differences. Children who are not capable of adapting their production to the target production until they reach the expected age are seen to show the so-called phonological disorder (GRUNWELL, 1981; YAVAS; MATZENAUER-HERNANDORENA; LAMPRECHT, 1992; MOTA, 2001; WERTZNER, 2003; MUNSON et al., 2010).

Phonetically speaking, the lack of adaptation to the production might occur due to children's problems involving acquisition and/or manipulation of acoustic cues (SCOBBIE et al., 2000; BERTI; MARINO, 2011). Children may resort to phonetically inappropriate cues for a given language (that is, inappropriate use of acoustic cues) and/or may use appropriate phonetic cues for the given language, but with an unexpected magnitude: with insufficient or exaggerated values, characterizing the so-called covert contrasts (SCOBBIE et al., 2000).

The term "covert contrast" was coined by Hewlett (1988) to describe what is categorized as phonemic contrast – auditorily unperceivable, yet acoustically and/or articulatorily detectable. Hence, a production which is auditorily perceived as either omission or category substitution may reveal, from the acoustic and/or

1 VOT is regarded as being the "[...] interval between the articulatory opening of a plosive consonant and the start of vocal chords vibration." (KENT; READ, 1992, p.108).

articulatory analysis, that the speaker is systematically producing differences to distinguish two phonemes (MACKEN; BARTON, 1980; SCOBBIE, 1998; HEWLETT; WATERS, 2004; BERTI, 2006; FREITAS, 2007; RODRIGUES, 2007; BERTI, 2010; MELO et al., 2011; BRASIL et al., 2012).

Scobbie (1998) performed an extensive bibliographic survey of all the authors who described the presence of the covert contrast, both among children with typical development and among children with a phonological disorder. The results show that covert contrasts were seen in the syllable structure, in the articulation mode, in voicing, in the place of articulation. It can be inferred that parameters involved in the contrast of a given phonological contrast are not immune to covert contrasts.

In the Brazilian literature, authors such as Berti (2006, 2010), Freitas (2007), Rodrigues (2007), Melo et al. (2012) and Brasil et al. (2012) described the presence of covert contrasts in the productions of children – with and without phonological disorders –, corroborating international studies on the omnipresence of covert contrasts (SCOBBIE, 1998). In general, the findings obtained from these studies revealed that acoustic cues used by children to mark contrasts may vary in terms of type and magnitude. There are essential and secondary cues. Furthermore, essential cues should be used within a certain magnitude so as to become effective in the perception of a given contrast. The presence of covert contrasts, identified through an acoustic analysis, proves that children have already started the process of establishing contrasts between two phoneme categories, and also provides evidence on which acoustic cues are primarily used by the subjects.

It is possible to understand from the reviewed literature that the use of an instrumental tool, acoustic and/or articulatory, in a speech production analysis, turns out to be necessary in order to investigate how children manipulate the cues before they can differentiate the contrasts.

However, it should be pointed out that studies in the Brazilian literature are still scarce when it comes to the exploration of different types of populations and also details of cues used by speakers. The investigated populations, the analyzed contrasts and the parameters used are not enough, neither to minutely describe the steps taken by children throughout the phonological acquisition process nor to promote rehabilitation of children with a phonological disorder, considering the types and magnitudes of the cues used to mark language contrasts.

Thus it is important to further descriptive research that focus on an instrumental approach so as to identify natural (or primary) and secondary parameters throughout the acquisition process. Based on a consistent description, it is possible, on one hand to propose a fast and effective treatment for children diagnosed with a phonological disorder, and on the other hand to observe the phonetic detail and its relevance in the scope of linguistic theories.

Hence this paper aims at verifying whether the covert contrast phenomenon is present in the speech production of children diagnosed with a phonological disorder, seeking to answer the following questions:

(i) Which are the acoustic cues that children with a phonological disorder manipulate when attempting to establish phoneme contrasts involving fricative sounds?
(ii) Do children with a phonological disorder prefer to use any acoustic parameters?

Our hypothesis is that children with a phonological disorder rely on secondary acoustic cues when attempting to establish language phoneme contrasts.

The fricative sounds were chosen in this investigation because they are seen to show a high incidence of problems for children with a phonological disorder (substitutions and omissions) (PATHA; TAKIUCHI, 2008).

Method

Sample

In order to perform this study, we used recordings belonging to a databank organized by the members of GPEL (Language Study Group), constituted of audio recordings of children in the process of typical and deviant language acquisition, attending full-time classes in the Children Municipal School Sítio do Pica-Pau Amarelo, located in Marília-São Paulo.

The students whose audio recordings were used in our investigation were attending a full-time class known as Infantil I. Initially, 23 audio recordings were selected from 23 monolingual boys and girls, four and five year old. The informed consent form was read and signed by their parents or guardians, complying with the demands of the Committee of Research Ethics. We chose to study this age group because this is a period when, according to Wertzner (2010), children are making the phonological system stable, which leads them to be more prone to errors, especially regarding some required adjustments in the production of fricative phonemes.

The audio recordings of the children were selected according to the following criteria: parents and/or guardians had to agree to participate in the research by reading and signing the informed consent form; children showing phonetic-phonological disorders in the phonoaudiological assessment; having at least three repetitions of the 96 words that compose the Instrument of Speech Assessment for Acoustic Analysis. Among the exclusion criteria were: information indicating any anatomical and/or physiological abnormality in the speech mechanism; information reporting any general speech impairment, such as difficulty to understand simple commands or lack of attention.

Then the speech therapist in charge of data collection managed to raise student-related information during the phonoaudiological and audiological assessment.

Among the 23 files that were selected in the beginning of data collection, 15 were dismissed because they did not meet the established criteria, which eventually left eight audio files for the research.

Among them, four files refer to boys and four to girls. Every child showed the so-called substitutions involving the fricative group.

After the audio files were selected, the recordings were edited by the researchers using the *software* PRAAT, separating each production in individual files, totaling 2,304 files (eight children x 96 words of IAFAC x three repetitions).

Experimental Procedures

The recordings used in this research were carried out by a speech therapist phonoaudiologist, a child at a time, in an acoustic booth set up in the Municipal School (EMEI), with a digital recorder (Marantz, model PMD 670), coupled to a cardioid dynamic vocal microphone (SHURE, model 8800).

In order to elicit the children's speech sample, we used the IAFAC (BERTI; PAGLIUSO; LACAVA, 2009). It is an instrument made up of 96 words, which is based on linguistic criteria, targeting specific aspects, namely phonetic-phonological context of words, accent pattern, grammatical category, number of syllables and syllabic pattern of the words. Such an instrument enables the analysis of the phonological system, since it contemplates all the 19 consonant phonemes of Brazilian Portuguese with a vowel context [i, a, u] in initial and middle syllable positions, complex onset and ordinary codas. In our instrument, each word is represented by a corresponding picture. Through a recreational activity, the words and pictures were shown to the children. Each child was asked to say the target word within the following sentence: "Say *target word* beautifully".

The sentence was used so as to control the intonation curve of each word, smoothing the ascending curve and certain features that the words might show, for example, a decrease in intensity, an increase in absolute duration, in case they were repeated isolated in a list.

The recordings were saved in individual files, and afterward each word was edited so as to enable the acoustic analysis.

Each recording was performed at least three times, and each child repeated the 96 IAFAC words. The recordings occurred in different days because this procedure is time-consuming and tiring. However, the time lapse between the first and third recording did not exceed a month.

Among the edited files, we selected only those containing a fricative syllable onset with vowel contexts /i,a,u/ (8 children x 3 repetitions x 6 fricatives x 3 vowel contexts = 432 files), which constituted the corpus of this research. Table 1 shows the selected words:

Table 1: Words of the IAFAC used in this research.

Fricatives	Context with [i]	Context with [a]	Context with [u]
[f]	Fita [ribbon]	Faca [knife]	Fuça [muzzle]
[v]	Viga [pillar]	Vaca [cow]	Vuba [grass]
[s]	Sica [proper nom]	Sapo [toad]	Suco [juice]
[ʃ]	Chica [proper nom]	Chave [key]	Chuva [rain]
[z]	Ziper [zipper]	Zaga [defense]	Zurro [braying]
[ʒ]	Jipe [jeep]	Jaca [jackfruit]	Juba [mane]

Source: Own elaboration.

Analysis

Perceptive-auditory assessment of productions

After the audio files were selected and edited, we performed a phonetic transcription of the first repetition of the 96 IAFAC words, through a perceptive-auditory assessment done by three evaluators.

The edited audio files were recorded on a CD-ROM and handed to the evaluators along with forms for notes regarding each transcription, containing 96 written words. The transcription task was explained orally the moment the material was handed out and consisted in phonetically transcribing the words produced by the children. For the final transcription of each word, at least two (66%) evaluators had to agree on the analyzed production.

The perceptive-auditory assessment was a fundamental step for this research, since it was the starting point for other analyses: contrastive analysis of the children's phonological system and also the acoustic analysis.

Contrastive analysis of children's phonological system

Based on the final transcription, we performed the contrastive speech analysis of the eight children.

The contrastive analysis was carried out according to Yavas, Hernandorena and Lamprecht (1992), who state that children's phonological systems can be compared to those of typical adult speakers (whose first language is Portuguese and not showing any phonological or phonetic impairment identified by native listeners). By resorting to children's speech variation, related to each contrastive phoneme of Brazilian Portuguese, we surveyed which of them were acquired effectively by children; which were being acquired; and which had not been acquired by children. This categorization was structured following these criteria: less than 50% correct answers – the child did not show to have the contrastive phoneme; 51% to 75% correct answers – the child showed to have the contrastive phoneme occurring with a substituting one; 76% to 85% correct answers – the child already acquired the contrastive phoneme; 86% to 100% - the contrastive phoneme was effectively acquired.

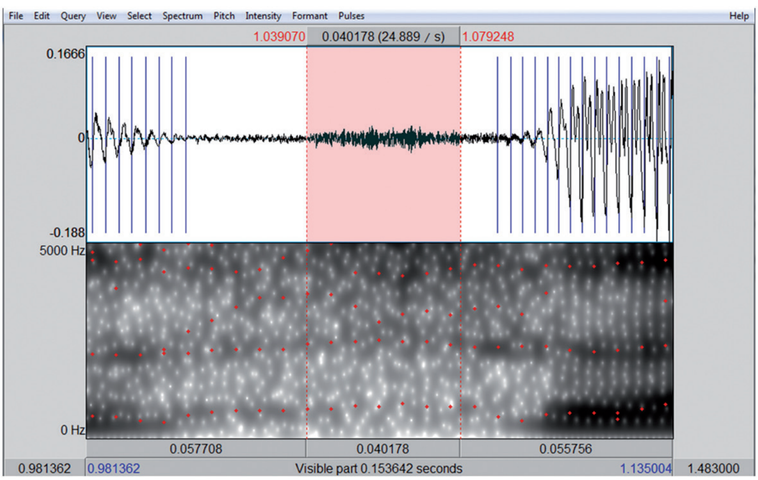
This analysis was followed by a characterization of the phonological profile of the eight children from the observation and characterization of deviant productions (incidence of omissions and substitutions) in simple attack.

Acoustic analysis

Finally, we performed an acoustic analysis of all the "phonemic neutralizations" involving the fricatives produced by children, according to acoustic parameters related to four spectral moments (centroid, variance, asymmetry and kurtosis), spectral peak minimum values and fricative relative duration.

For all the spectral parameters adopted in the analysis, we selected an approximate 40ms window in the middle part of the fricatives, which is seen to be less affected by the transition of other sounds, that is, the co-articulation effects are less observed, as shown in Figure 1.

Figure 1 – Selection of 40ms of the more stable part of the fricative [s].



Source: Own elaboration.

After selecting the gap, we extracted automatically the Fast Fourier Transform (FFT) following these parameters: **view range** (Hz): 0 to 11025 Hz; **window length** (s): 0.002*;* **dynamic range** (dB): 70. Next, we returned to the window **Objects** of PRAAT and selected the option **Query, Get central moment** in order to automatically obtain the relative values of the spectral moments.

It is worth mentioning that the peak value that precedes the ascending frequency of the minimum limit of the spectral peak was manually extracted from each fricative, from the FFT.

Concerning the measures of relative durations, that is, the measures that correspond to the percentage that a sound occupies within a greater unit, for example, a word, the following criteria were used: for voiceless fricatives, we selected the part that corresponds to the last regular pulse of the post-stressed vowel up to the first regular pulse of the stressed vowel; for the voiced fricatives, the middle part between the post-stressed vowel and the stressed vowel.

The normalization (or relative duration, in this case) was carried out to neutralize prosodic features, such as speech speed. This allows for a more precise comparison involving durational data coming from distinct speakers.

Statistical Analysis

The software used in the statistical analysis was STATISTICA, version 7.0. The statistical analysis used in our study was the one-way ANOVA, having as dependent variables all the acoustic parameters adopted and as independent variables the phoneme contrast analyzed.

We established a significance level to be 0.05. Values ranging from 0.05 to 0.1 were considered outliers.

The statistical analysis relied on the comparison of the values obtained for each parameter for each repetition, both for the so-called substituted phoneme and for the actual corresponding phoneme.

Thus, an example of a comparison can be seen in Table 2. The selected example shows a child replacing [s] with [ʃ] in all the vowel contexts.

Table 2: Words used in data collection. The phoneme analyzed is in an initial position of the words above.

Words with a substituted phoneme	Words containing a phoneme to be compared
SAPO [toad]	CHAVE [key]
SICA	CHICA
SUCO [juice]	CHUVA [rain]

Source: Own elaboration.

Results and discussion

Perceptive-auditory analysis

By resorting to the perceptive-auditory analysis of the first repetition (R1) with the eight children, performed by the three evaluators, we surveyed all the substitutions identified by the evaluators, eventually reaching 121 substitutions involving the following groups: stops, fricatives, affricates, nasals, lateral liquids and non liquids in all syllable positions (attack and coda).

Nevertheless, we decided to select only the occurrences of substitution involving simple attack positions, focus of this research, which resulted in 81 substitutions, as shown in Table 1.

Table 1: Occurrence of substitution in simple attack according to sound group.

Sound group / Children	Stops	Fricatives	Africates	Nasals	Lateral Liquids	Non Liquids
C1	5	14	1	6	2	3
C2	0	0	2	2	2	0
C3	0	6	0	1	0	0
C4	1	5	1	0	0	0
C5	0	3	0	0	2	2
C6	0	1	0	6	2	1
C7	0	1	0	1	1	0
C8	3	2	0	1	1	3
TOTAL	**9**	**32**	**4**	**17**	**10**	**9**

Source: Own elaboration.

According to Table 1, there is a prevalence of substitutions involving the fricative sounds, with 32 substitutions in simple attack; followed by the nasal group, with 17 substitutions; lateral liquids, with 10 occurences of substitutions; and non lateral liquids and stops, with 9 substitutions; and affricates with a low incidence of substitutions.

The prevalence of substitutions involving the fricatives was also observed in a study developed by Keske-Soares et al. (2009), who found out that the fricatives were the most affected sound group while studying the speech of five children with phonological disorders.

Since the acoustic analysis required not only the first repetitions but also three or more repetitions for each child, it was important to perform the perceptive-auditory assessment of all the recordings so as to check whether the substitution identified in the first recording would be maintained in the remainder. During this phase, we observed that the 8 substitutions, out of the 32 identified in the first repetition, were not seen in the others, which indicates a contrast stabilization process in some children. Hence, the productions of 3 children (C2, C6 and C8) were excluded from the study.

After hearing and characterizing the substitutions, there were 24 occurrences of substitutions involving the fricatives, which were identified in the 3 repetitions.

Out of 24 substitutions, 17 (71%) involved the place of articulation (for example: [s]→[ʃ]), 6 (25%) involving voicing ([v]→[f]), 1 (4%) involving both the place of articulation and voicing ([z]→[ʃ]).

The substitution relation performed by the children involving the fricatives can be seen in the Table, organized in function of the substitution pattern.

Table 2: Number of substitutions of fricatives in function of substitution type for each child.

Child / Type of subst.	Substitution involving place of articulation	Substitution involving voicing	Substitution involving place and voicing
C1	3	6	-
C3	5	-	1
C4	5	-	-
C5	3	-	-
C7	1	-	-

Source: Own elaboration.

Acoustic analysis of the so-called "substitutions"

The data shown here are organized according to the categories described previously, that is, "substitutions" involving the place of articulation, voicing, place of articulation + voicing, and, also, separated according to the vowel context [i, a, u].

Substitutions involving the place of articulation

The mean values found for each parameter in the so-called substitutions involving the place of articulation are displayed in Table 3. The values in bold refer to p-values less than 0.05; the underlined values, the outliers, refer to p-values between 0.05 and 0.1, obtained after the statistical analysis, separated according to the vowel context.

Table 3: Mean values found for each parameter considering the "substitutions" involving the articulation point (*standing for substituted, *1 standing for target).

Child	Subst. of place	Vowel	Spectral peak (Hz)	M1 (Hz)	M2 (MHz)	M3	M4	Rel. Dur. (ms)
C3	[s] *	[a]	1671.60	5873.88	3.40	0.25	-0.19	143
		[i]	1705.14	**5518.96**	2.40	0.48	0.57	140
		[u]	1421.51	4935.20	4.40	0.22	-0.19	**155**
	[ʃ] *1	[a]	1765.02	5436.82	2.69	0.82	0.58	158
		[i]	1757.10	**5063.05**	2.69	0.82	0.58	157
		[u]	1413.08	1087.32	4.30	0.87	1.18	**122**
	[z] *	[a]	**1618.23**	1684.66	1.69	**3.92**	21.85	118
		[u]	1397.05	4216.96	3.94	0.12	-0.09	110
	[ʒ] *1	[a]	**1405.24**	3254.06	5.84	**1.08**	2.14	128
		[u]	1463.34	3190.39	3.52	5.49	54.58	133
C5	[s] *	[a]	1642.12	5182.04	3.86	0.44	1.82	255
		[u]	1615.92	4165.14	2.58	0.77	1.66	149
	[ʃ] *1	[a]	1798,17	5034.34	2.56	0.81	4.99	110
		[u]	1650.60	4021.46	2.99	0.62	2.15	135
	[z] *	[u]	1583.56	392.76	0.93	1.03	23.68	127
	[ʒ] *1	[u]	1555.81	2798.72	1.38	4.60	64.37	158
C4	[z]*	[u]	2222.28	753.97	1.32	9.25	129.64	**100**
	[ʒ] *1	[u]	2272.48	1120.64	3.14	3.52	15.11	**107**
	[ʃ] *	[a]	1637.06	2056.42	6.02	1.86	4.69	98
		[i]	2142.31	2696.63	5.21	3.33	29.54	149
	[s]*1	[a]	2214.30	1104.47	4.85	3.06	11.60	110
		[i]	2077.47	4814.25	5.77	-0.31	5.26	160
	[ʒ]*	[a]	2501.35	748.70	2.58	4.56	144.36	122
		[i]	1908.53	1443.35	1.71	10.09	193.96	**114**
	[z]*1	[a]	1547.88	2799.25	6.77	10.73	321.59	138
		[i]	1393.60	712.77	2.87	12.60	323.58	**180**
C7	[z]*	[u]	1548.55	3842.96	6.54	4.97	1.02	**125**
	[ʒ] *1	[u]	1434.61	2796.78	4.14	1.61	4.03	**105**
C1	[s] *	[a]	2862.74	4174.67	8.60	0.35	**-0.38**	255
		[i]	2128.97	5934.30	5.62	-0.26	-0.54	147
		[u]	2003.69	**5764.37**	5.64	**-0.23**	**-0.54**	137
	[ʃ] *1	[a]	2182.65	5545.56	6.45	-0.15	**-0.49**	138
		[i]	1834.69	5627.49	4.84	-0.29	0.35	149
		[u]	1641.57	**3691.85**	3.04	**1.37**	**2.16**	129

Note: C: child; M1: Centroid; M2: Variance; M3: Asymmetry; M4: Kurtosis.

Bold: $p<0.05$; _: outlier value: $0.05 < p < 0.1$

Source: Own elaboration.

In Table 3, the mean values can be seen for each parameter obtained in the acoustic analysis, by comparing the productions evaluated as "substituted" (indicated by * in the white cells) and the productions evaluated as target (indicated by *1 in the gray cells). For example, C3 shows that the mean value of the spectral peak of [s] evaluated as [ʃ], in the vowel context [a], was 1671.60 Hz, whereas the mean value of the spectral peak of the target production [ʃ], in the same vowel context, was equal to 1765.02 Hz, not showing statistically significant difference. On the other hand, we see significant difference when the mean value of the spectral peak of the production [z] evaluated as [ʒ] of the same child, in the same vowel context – 1618.23 Hz – and compare to the value obtained in [ʒ] produced as target – 1405.24 Hz.

Overall, the analysis of the Table above shows 17 occurrences of substitutions involving the point of articulation: six occurred in the vowel context of [a]; four, in the context of [i]; and seven, in the context of [u].

Concerning the presence of covert contrast, out of the 17 substitutions involving the place of articulation (seen in the white cells), 10 (58%) revealed the presence of covert contrasts. Even though children identified them as homophones, they distinguished the fricatives investigated by manipulating at least one acoustic cue (seen in the Table in bold and underlined values).

These findings corroborate the data available in international and national literature. According to a bibliographic survey performed by Scobbie (1998), covert contrasts were identified when establishing the voicing contrast, of place and mode of articulation, among children with typical development and among children with a phonological disorder. Li, Edward e Beckman (2009) studied the speech production of two and three-year-olds (with typical development) and found covert contrasts accounting to 26% among English speakers and 11% among Japanese speakers. Concerning Brazilian studies, a higher percentage was found by Berti (2010): 80% of productions evaluated as category substitution [t] →[k] show, after the acoustic analysis, the presence of covert contrasts in children with a phonological disorder, and 57% in children at the acquisition phase. However, despite the high percentage of identification of covert contrasts, the range of percentage variation might be explained thanks to the effect of age group in the population under investigation. It is possible to infer that the higher the subjects' age group, the higher the percentage of identification of covert contrasts.

Regarding the type of acoustic cues used to mark differences among the fricatives and the point of articulation, we found that children relied not only on cues that refer to spectral details of the fricatives, but also on cues that refer to the temporal pattern (relative duration).

The results in Table 3 show the occurrence of manipulation of the parameter regarding the minimum limit of the spectral peak by C1, in an attempt to distinguish [z] and [ʒ] only in the vowel context of [a]. Nevertheless, Berti (2006) analyzed the contrast between the fricatives [s] and [ʃ] and concluded that this parameter is appropriate so as to differentiate the analyzed phonemes in all the vowel contexts, which corroborates the findings of Freitas (2007) and Jongman, Wayland and Wong (2000).

Concerning the mobilization of the first spectral moment (centroid), only two productions proved to show covert contrasts. The parameter was manipulated (in the distinction of [s] and [ʃ] by C3 in the context of [i] and C1 in the context of [u]). In a study performed by Berti (2006), tackling the same contrast, it was found that M1 was appropriate to differentiate voiced coronal fricatives, in the contexts with [a] and [i] among children with a phonological disorder. In a previous study, Rinaldi (2010) concludes that children with typical development manipulate the centroid parameter to differentiate the point of articulation for fricatives of Brazilian Portuguese. Jongman, Wayland and Wong (2000) also report similar findings while dealing with fricatives in the English language. Hence, in this study, centroid does not seem to be the preferred parameter among children with a phonological disorder.

As for the parameter of variance, we had only one outlier when attempting to differentiate [z] and [ʒ] by C3, corroborating the results of Berti (2006), in which variance does not differentiate [s] and [ʃ] in vowel contexts, among children with and without a phonological disorder. These data differ from those reported by Jongman, Wayland and Wong (2000), who did not find difference between [v] and [f], and Freitas (2007), who found variance for the places of articulation of [s] and [ʃ] in the contexts of [i] and [u], among children with a phonological disorder.

For the asymmetry parameter (M3), in two productions characterized as covert contrasts coming from C3 and C1, the parameter was manipulated in an attempt to promote distinction between the place of articulation of [z] and that of [ʒ] in the context of [a] for C3, and [s] and [ʃ] for C1 in the context of [u]. This result is similar to that of Freitas (2007), in which children with a phonological disorder also manipulated such a parameter with variation in the vowel context of [i] and [u], whereas children without a phonological disorder manipulated the asymmetry parameter in all the vowel contexts. The investigation carried out by Berti (2006), and further investigations, verified that children with a phonological disorder manipulated such a parameter in the vowel context of [i] and [a].

Regarding the parameter of kurtosis, it is likely to have happened in two productions of C1 to differentiate the place of articulation of [s] and [ʃ] in the context of [a] and [u]. Nevertheless, the studies carried out by Berti (2006) and Rinaldi (2010) revealed that such a parameter was not appropriate to differentiate the place of articulation between [s] and [ʃ] for Brazilian Portuguese-speaking children, which is different from the studies in English performed by Jongman, Wayland and Wong (2000), where kurtosis was not found to differentiate [v] and [f], [z] and [s]. Therefore, such a parameter does not seem to be fundamental to guarantee distinction among Brazilian Portuguese fricatives, since typical children who participated in the studies – despite the lack of reliance on kurtosis – produced them allowing for identification of two fricatives by the listeners.

Regarding the parameter of duration, four occurrences of manipulation of this cue were found in the attempt to establish contrast between fricatives in the investigated productions. However, according to Rinaldi (2010), the parameter of duration is not appropriate to differentiate the fricatives in terms of place of articulations, which suggests that these children with a phonological disorder rely on secondary cues in order to distinguish Brazilian Portuguese fricatives.

In short, out of ten occurrences of covert contrasts, four occurred in the vowel context of [a], two in the context of [i] and four in the context of [u]. The influence of the vowel context in the manipulation of acoustic cues has been previously described in the literature by authors such as Berti (2006) and Freitas (2007) and has been corroborated in our investigation. Furthermore, the type of acoustic cue manipulated by children with a phonological disorder seems to be the non-preferred in the language, that is, those cues described in the analysis of productions of children with a typical language development.

Substitutions involving voiced stops

Only C1 showed productions evaluated as substitutions that involved voicing contrast between fricatives. In Table 4, the mean values of each parameter obtained in the acoustic analysis can be seen, when comparing the productions evaluated as "substitutions" (indicated as * in white cells) and the productions evaluated as target (indicated as ^{*1} in the gray cells). We point out that the values in bold refer to p-values less than 0.05; the underlined values refer to p-values ranging from 0.05 to 0.1, called outliers, obtained after the statistical analysis, sorted in function of the vowel context.

Table 4: Mean values found for each parameter considering the substitutions involving voicing (*standing for substitutions, *1 standing for target).

Child	SoundSubst.	Vowel	Spectral Peak (Hz)	M1 (Hz)	M2 (MHz)	M3	M4	Rel. Dur. (ms)
C1	**[ʒ]***	[a]	2071.47	5717.09	6.17	-0.31	0.12	124
		[i]	**2158.97**	**5381.58**	4.46	**0.30**	0.73	134
		[u]	1813.88	4048.15	2.57	1.35	5.18	122
	[ʃ]*1	[a]	2182.65	5545.56	6.45	-0.15	-0.49	133
		[i]	**1834.69**	**5627.49**	4.84	**-0.29**	0.35	144
		[u]	1641.57	3691.85	3.04	1.37	2.16	125
	[v]*	[a]	1409.80	2396.90	4.08	1.55	3.06	96
		[i]	1272.66	1744.37	4.88	2.19	5.44	117
		[u]	**1091.26**	4040.94	7.10	0.10	0.57	138
	[f] *1	[a]	1622.90	1809.23	3.88	2.78	13.40	94
		[i]	1651.66	2185.15	6.38	2.43	12.73	103
		[u]	**1457.00**	3225.40	5.25	1.09	2.95	145

Note: C: Child; M1: Centroid; M2: Variance; M3: Asymmetry; M4: Kurtosis.

Bold: $p<0.05$; _: outlier: $0.05 < p < 0.1$

Source: Own elaboration.

Based on the Table above, it can be seen that out of six "substitutions" involving voicing, three revealed the presence of covert contrasts. Phoneme distinction between voiceless and voiced fricatives was primarily marked by the parameter related to spectral limit of the minimum peak.

However, Rinaldi (2010) showed that typical children differentiated fricative voicing through the following acoustic parameters: centroid, asymmetry and duration. Likewise, in the English language, Jongman, Wayland and Wong (2000) found out that the four spectral moments differentiate the fricatives when it comes to voicing. Hence, C1 is likely to rely on secondary parameters – less appropriate for the language, since C1 does not manipulate cues commonly used by typical children to mark voicing distinction among fricatives.

Substitutions involving place of articulation and voicing

In C3, only one "substitution" was found, involving both the place of articulation and voicing. The mean values of each parameters are shown in Table 5:

Table 5: Mean values found for each parameter considering the substitutions involving the place of articulation + voicing. (* standing for substitutions, *1 standing for target).

Child	Subst of place + sound	Vowel	Spectral peak (Hz)	M1 (Hz)	M2 (MHz)	M3	M4	Rel. Dur. (ms)
C3	**[z]** *	[i]	1724.58	3830.37	3.03	2.16	7.99	144
	[ʃ] *1	[i]	1757.10	5063.05	2.69	0.82	0.58	155

Note: C: child; M1: Centroid; M2: Variance; M3: Asymmetry; M4: Kurtosis.
Bold: $p<0.05$; _: outlier p: $0.05 < p < 0.1$

Source: Own elaboration.

The observation of Table 5 does not point at the presence of covert contrasts for the substitution involving the place of articulation and voicing, even though Rinaldi (2010) indicated that the parameters regarding spectral moments M1 e M3 were appropriate to differentiate the interaction between the place of articulation and sounds of Brazilian Portuguese fricatives.

Concluding remarks

Our research has sought to identify the presence of covert contrasts in speech production among children with the so-called phonological disorder. More specifically, we have aimed at answering the following questions:

(i) Which are the acoustic cues that children with a phonological disorder manipulate when attempting to establish phoneme contrasts involving fricative sounds?

(ii) Do children with a phonological disorder prefer to use any acoustic parameters?

After the data analysis, it was possible to see by means of acoustic and statistical analysis that several substitutions identified as homophones, by the evaluators, revealed subtle and unperceivable differences in hearing: the so-called covert contrasts. Such differences account to 54% of the total "substitutions" identified through an impressionistic approach.

Regarding the type of acoustic cues manipulated by the children with phonological disorders, we hypothesized that they are likely to rely on secondary acoustic cues in an attempt to establish phoneme contrasts in the language. The hypothesis was confirmed after data analysis, since the parameters of kurtosis and duration, which, according to Rinaldi (2010) and Berti (2006), are not fundamental in the distinction of fricatives in the Brazilian Portuguese, were the most commonly used cues by the children, in an attempt to differentiate the fricatives in the productions. As for the centroid parameter, for example, reported by Berti (2006), Freitas (2007), Rinaldi (2010) as being appropriate in the distinction of fricatives in Brazilian Portuguese, it was, along with the variance, the least used parameter used to distinguish the fricatives among children with a phonological disorder.

Furthermore, there is a need to use a bigger sample, a wider variety of sound groups and check whether the preference over secondary cues is maintained.

Finally, the data in our study indicate the importance of considering phonetic features in the construction of the phonological system by children. When a phonological contrast is believed to be the result of a set of cues that are differentiated in type and magnitude, this becomes fundamental in the manipulation process of individual cues by the children until they reach an effective contrast.

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CORRÊA, A. P. dos S.; BERTI, L. Estabelecimento do contraste entre as fricativas por crianças com transtorno fonológico: manipulação de pistas acústicas. **Alfa**, São Paulo, v.59, n.2, p.355-374, 2015.

■ *RESUMO: O presente trabalho versa sobre a presença de contrastes encobertos na fala de crianças com transtorno fonológico. A hipótese perseguida é a de que as crianças com transtorno fonológico se ancoram em pistas acústicas secundárias na tentativa de estabelecer contrastes fônicos da língua. Para tanto, foram utilizadas cinco gravações em áudio, advindas de cinco crianças entre 4 e 5 anos com transtorno fonológico, que apresentavam as chamadas "substituições fônicas" envolvendo a classe de sons das fricativas. Os dados foram editados e analisados com o uso do software PRAAT. Foi realizada uma transcrição fonética da primeira repetição (R1) de cada criança, por três juízes, e considerada a concordância de 66%. A partir desta transcrição, foi realizada a análise fonológica contrastiva acústica de todas as "substituições" envolvendo a classe de sons das fricativas, a partir de seis parâmetros.*

Verificou-se a existência de contrastes encobertos nas produções tidas como homófonas auditivamente, representando um total de 54% do total das substituições identificadas pelos juízes. As crianças com transtorno fonológico ancoram-se preferencialmente em pistas acústicas secundárias na tentativa de distinguir os fones fricativos. Os dados obtidos neste estudo permitem reflexão acerca da importância de se considerar o detalhe fonético no interior dos modelos fonológicos.

- *PALAVRAS-CHAVE: Aquisição Fonológica. Fonética. Análise Acústica. Fricativas. Transtorno Fonológico.*

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