

**ARTICULATORY  
GESTURES IN  
CHILDREN  
WITH SPEECH  
SOUND  
DISORDERS:  
ULTRASOUND  
DATA**

**GESTOS ARTICULATÓRIOS EM CRIANÇAS COM TRANSTORNOS DOS SONS DA FALA:  
DADOS DE ULTRASSOM**

**GESTOS ARTICULATORIOS EN NIÑOS CON TRASTORNOS DEL SONIDO DEL HABLA: DATOS  
DE ULTRASONIDOS**

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**ABSTRACT:** This study aimed at comparing the tongue contours of children with phonological disorders (PD) and of children with childhood apraxia of speech (CAS). The hypothesis was that children with PD have different tongue contours from those with CAS in Brazilian Portuguese. Five children with PD and five with CAS participated in this study. Data were collected and analyzed with the Articulate Assistant Advanced software. The target segment was analyzed using the frame corresponding to the point of maximum constriction of the tongue. Statistical analysis consisted of an SSANOVA. The data were pooled and the tongue contours of the children with PD and CAS were used to fit an SSANOVA for each target segment. The hypothesis was partially corroborated. Results showed differences in tongue contours between children with PD and with CAS for correct productions of plosives. Children with PD showed different articulation strategies in most correct and incorrect productions when compared to children with CAS.

**KEYWORDS:** Articulatory Analysis. Language Acquisition. Phonological Acquisition. Brazilian Portuguese.

**RESUMO:** O objetivo deste estudo foi comparar os contornos da língua de crianças com desvio fonológico (DF) e com apraxia de fala na infância (AFI). A hipótese foi de que crianças com DF apresentam contornos de língua distintos das crianças com AFI no português brasileiro. Cinco com DF e cinco com AFI participaram deste estudo. Os dados foram coletados e analisados com o software Articulate Assistant Advanced. O segmento-alvo foi analisado por meio do *frame* correspondente ao ponto máximo de constricção da língua. A análise estatística consistiu em um SSANOVA. Os contornos da língua foram agrupados por segmento-alvo e a SSANOVA comparou os grupos de crianças com DF e com AFI. A hipótese foi parcialmente corroborada. Os resultados mostraram diferenças nos contornos da língua entre as crianças com DF e AFI para produções corretas das plosivas. Crianças com DF apresentam estratégias de produção diferentes na maioria das produções corretas e incorretas quando comparadas às crianças com AFI.

**PALAVRAS-CHAVE:** Análise Articulatória. Aquisição de linguagem. Aquisição fonológica. Português do Brasil.

**RESUMEN:** Este estudio tuvo como objetivo comparar los contornos de la lengua de niños con trastornos fonológicos (TF) y con apraxia del habla infantil (AHI). La hipótesis fue que los niños con TF tienen contornos de lengua diferentes a los que tienen AHI en portugués brasileño. Cinco niños con TF y cinco con AHI participaron en este estudio. Los datos fueron recopilados y analizados con el software Articulate Assistant Advanced. TF segmento objetivo se analizó utilizando el marco correspondiente al punto de máxima constricción de la lengua. El análisis estadístico consistió en un SSANOVA. Se agruparon los datos y se utilizaron los contornos de la lengua de los niños con TF y con AHI para ajustar un SSANOVA para cada segmento objetivo. La hipótesis fue parcialmente corroborada. Los resultados mostraron diferencias en los contornos de la lengua entre los niños con TF y con AHI para la producción correcta de las oclusivas. Los niños con TF mostraron diferentes estrategias de articulación en la mayoría de las producciones correctas e incorrectas en comparación con los niños con CAS.

**PALABRAS CLAVE:** Análisis articulatorio. Adquisición de lenguaje. Adquisición fonológica. Portugués Brasileño.

## 1 INTRODUCTION

The phonological acquisition of Brazilian children with typical development involves acquiring /t/ and /k/ from 3 years to 3 years and 5 months of age (CERON; KESKE-SOARES, 2017; FREITAS, 2004). If children cannot establish such phonic contrast at that age, they are considered to have an atypical production, displaying the phonological process of velar fronting. Velar fronting (/k/ → [t] or /g/ → [d]) occurs when a child tries to produce the target velar sounds ([k] or [g]), but produces a plosive aurally perceived as alveolar, [t] and [d], respectively.

Both Phonological Disorders (PD) and Childhood Apraxia of Speech (CAS) are cases of Speech Sound Disorders (SSDs), which consist of deficits in the production of individual speech sounds or sequences of speech sounds caused by inadequate planning, control or coordination of structures of the oral tract. SSDs is a term related to any combination of difficulties with perception, motor production, and/or phonological representation of speech segments (including phonotactic rules that govern syllable shape, structure, stress, as well as prosody) that impact speech intelligibility (ASHA, 2007; ASHA, 2017; SHRIBERG; WREN, 2019).

There are common characteristics between children with PD and children with CAS, such as: (a) consonant distortions; (b) reduced errors of consonant omissions and substitutions (SHRIBERG *et al.*, 1997); and (c) distinct characteristics, because they produce consistent errors that form patterns in PD and CAS. Children with CAS, however, present a high level of token-to-token variability.

Children with PD have deficits in their knowledge of phonetic segments or phonological rules, causing substitutions, omissions and/or distortions of speech (INGRAM, 1976; YAVAŞ; HERNANDORENA; LAMPRECHT, 2002; WERTZNER, 2003). The difficulty in realizing the mental representation of the phonological rule implies a problem related to the use of phonological rules of a language (WERTZNER; OLIVEIRA, 2002). According to the consensus among investigators, children with CAS have speech errors due to the disordered planning and programming of speech movements (ASHA, 2007; 2017).

CAS is mainly characterized by at least 4 out of 11 diagnostic markers: (a) vowel distortions; (b) difficulty achieving initial articulatory configurations or transitional movement gestures; (c) equal stress or lexical stress errors; (d) distorted substitutions; (e) syllable segregation; (f) groping; (g) intrusive schwa; (h) voicing errors; (i) slow rate/slow diadochokinetic rates; and (j) increased difficulty with multisyllabic words (SHRIBERG; POTTER; STRAND, 2011; ASHA, 2017).

Technological advances in the development of instruments of analysis of speech production have contributed to investigating speech “errors” through acoustic and/or articulatory devices, which provide greater detail regarding the process of speech production (LEE; WRENCH; SANCIBRIAN, 2015; CLELAND; SCOBIE; WRENCH, 2015; OLIVERA; BERTI, 2019).

Studies involving articulatory analysis (GIBBON, 1999; GIBBON; WOOD, 2002; GOOZÉE *et al.*, 2007; BERTI; BOER; BRESSMANN, 2016) have pointed out that children diagnosed with PD, despite not having any organic disorders, have motor restrictions in speech due to delays or deviations in the control of tongue regions (GIBBON, 1999). Research using electropalatography (EPG) (GIBBON, 1999) showed that in an attempt to produce the target sound, the child has difficulties in coordinating refined gestures of the tongue, not being able, for example, to distinguish gestures from the tip of the tongue, from the body of the tongue and the lateral margins of the tongue towards the palate, named by Gibbon (1999) as “undifferentiated lingual gestures”. The occurrence of these undifferentiated lingual gestures between the regions of the tongue as well as difficulties in symbolic representation of sounds have elucidated that children with PD have motor difficulties that must be associated with immature or deviant motor control related to the lever system and/or as a result of the compensation mechanism to neutralize disorders of fine motor control of the tip of the tongue.

Articulatory studies involving children with CAS are scarce. A previous study (KOCJANCIC, 2010) that analyzed ultrasound data of Scottish adolescents with CAS producing simple syllables (consonant-vowel) and complex syllables (consonant, consonant and vowel) identified smaller tongue movement in the vertical and horizontal directions when compared to data of children with no speech disorders.

Irfana and Sreedev (2015) found, in productions of children with CAS, speakers of Kannada, restricted tongue movements in the vertical and horizontal axes of the vocal tract when compared to a control group, corroborating Kocjancic’s data (2010). The motor restrictions may cause imprecisions and variabilities between articulators and variations of articulators were more evident in the posterior regions of the tongue when compared to the anterior region.

From the studies above, it is possible to verify that both groups of children would have difficulties in speech production, but there is still a gap in the description of articulatory productions between these two groups of children (with CAS and with PD), which are often confused in diagnostic markers. Given the scarcity of studies that seek to distinguish between Brazilian Portuguese-speaking children with PD and those with CAS, especially using instrumental and articulatory methods, it is necessary to further this type of investigation in order to unravel knowledge on speech production.

Therefore, this study aimed at comparing the tongue contours of Brazilian children with Phonological Disorders (PD) and Brazilian children with Childhood Apraxia of Speech (CAS) when producing two plosive consonants of Brazilian Portuguese, /t/ and /k/. The

hypothesis to be tested is that the tongue contours of children with PD are different from those with CAS in Brazilian Portuguese (BP).

## 2 METHODOLOGY

### 2.1 PARTICIPANTS

This research was approved (n° 2.564.168/2018) (CAAE: 85163518.0.0000.5406) by the Research Ethics Committee of the São Paulo State University.

Ten Brazilian Portuguese-speaking children (5 with PD and 5 with CAS) aged between 5 years and 6 years and 9 months of age, 9 male and 1 female, were tested using speech production measurements. All children lived in the city of Marília, in the state of São Paulo, Brazil, and those diagnosed with CAS were under speech therapy for at least six months. The evaluation tasks were conducted and scored by a certified speech-language pathologist. The distribution of children with PD and with CAS is shown in Table 1.

Children	Gender	Clinical Conditional	Chronological age	PCC-R
Child 1	Male	Phonological Disorders	6 years 4 months	66,96
Child 2	Male	Phonological Disorders	5 years 11 months	77,55
Child 3	Male	Phonological Disorders	6 years	56,36
Child 4	Male	Phonological Disorders	5 years 2 months	25,43
Child 5	Male	Phonological Disorders	6 years 3 months	68,42
Child 6	Male	Childhood apraxia of speech	6 years 6 months	48
Child 7	Male	Childhood apraxia of speech	7 years 5 months	74
Child 8	Male	Childhood apraxia of speech	5 years 11 months	55
Child 9	Male	Childhood apraxia of speech	5 years	64
Child 10	Female	Childhood apraxia of speech	7 years 7 months	69,16

PCC-R: Percentage of Correct Consonant - Revised

**Table 1:** Distribution of children regarding their clinical identification, gender, chronological age and PCC-R

**Source:** Authors

Children with PD and with CAS (clinically evaluated by speech therapists) underwent speech and language evaluations: audiological assessment, orofacial motricity and language skills assessment (comprehensive and receptive language).

To confirm the diagnoses of CAS, children of CAS underwent tests using speech production measurements: revised measurement of correct consonants percentage (PCC-R) (SHRIBERG *et al.*, 1997); child phonological assessment for BP-speaking children (YAVAŞ; HERNANDORENA; LAMPRECHT, 2002); correct consonants percentage (PCC) by Multisyllabic Word Repetition Task (OLIVEIRA *et al.*, 2020); Percentage of Correct Lexical Stress, also from Multisyllabic Word Repetition Task (MWR)

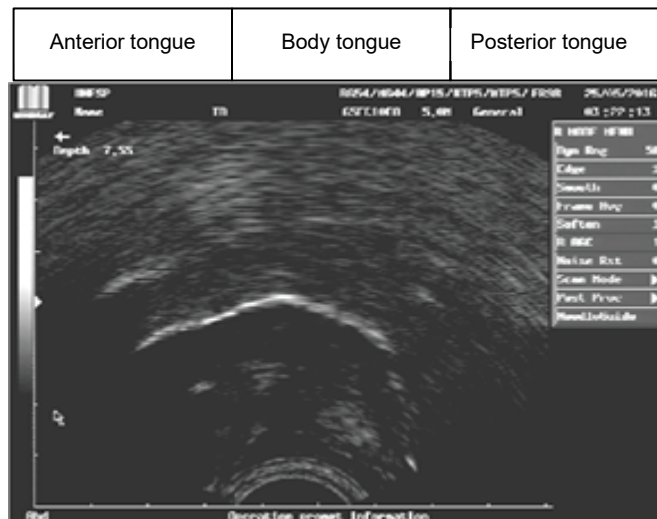
(PRESTON; EDWARDS, 2007; OLIVEIRA *et al.*, 2020); Emphatic Stress Task (EST) (SHRIBERG *et al.*, 2010; OLIVEIRA *et al.*, 2020); Inconsistency Task (IT) (MARQUARDT; JACKS; DAVIS, 2004; PRESTON; KOENIG, 2011; OLIVEIRA *et al.*, 2020); and Maximum Performance Tasks (MPT) (THOONEN *et al.*, 1999; OLIVEIRA *et al.*, 2020).

The exclusion criteria used in this study were: presence of intellectual and neurological disorders, presence of anatomical-morphological structural impairments that may impair speech production (for example, cleft lip and palate), and presence of otologic/auditory impairments. The speech sample consists of two words containing initial plosives /t/ and /k/, 'taco' /'tako/ (baseball bat) and 'capa' /'kapa/ (cape). To generate the corpus, we used pictures corresponding to the words. The images were shown on a computer screen running the Articulate Assistant Advanced (AAA) software. For each word, the children looked at the images and produced five repetitions. The three best recordings (concerning image quality) were used in the analysis.

## 2.2 RECORDING PROCEDURES

The children were recorded in Marília (São Paulo - Brazil) at São Paulo State University. The equipment available in the Laboratory of Acoustic Analysis (LAAc) used in this study was: a portable ultrasound device (model DP 6600); a sound-proof booth; a unidirectional microphone, a micro-convex transducer linked to a computer, and a head stabilizer. The recordings were done in the first semester of 2016.

Data collection was conducted using the Articulate Assistant Advanced software (AAA) (Articulate Instruments Ltd). The target segments were /t/ for /'tako/ and /k/ for /'kapa/. An example of a tongue contour is given in Figure 1.



**Figure 1:** Ultrasound image of the tongue contour of one child with phonological disorders; from left to right, the arrows indicate the anterior and posterior regions of tongue, respectively.

**Source:** Authors

## 2.3 AUDITORY-PERCEPTUAL ANALYSIS

The sound recordings of the target words were exported from the Articulate Assistant Advanced software. The audio files were sent to judges through Google Drive. Perceptual evaluations were performed independently by three experienced Speech-Language Pathologists from Marília (São Paulo - Brazil). The judges were master's and PhD students with experience in Articulatory Experimental Phonetics and Speech Sounds Disorders, as well as in ultrasound analysis.

Stimuli were organized randomly to avoid patterns of responses. The judges evaluated whether the target phoneme was correct or incorrect. If it was incorrect, they should transcribe the word as they heard it. The agreement of at least 2 judges was used for each stimulus. The judges were instructed to use headphones and to listen to the data as many times as needed. From the auditory-perceptual analysis, children's productions were subgrouped into correct and incorrect productions, which were analyzed separately.

#### 2.4. ARTICULATORY ANALYSIS

The tongue contour was drawn semi-automatically using the AAA software. For the quantitative ultrasound analysis, distance measurements were extracted from 42 frames corresponding to the maximum amplitude of constriction of the tongue for the production of each phoneme. As the ultrasound recording has several frames (images) per second, a period corresponding to the point of maximum constriction of the tongue to produce each target segment was selected. These measurements were analyzed using a Smoothing Spline Analysis of Variance (SSANOVA) (DAVIDSON, 2006) in R (R Core Team, 2020), with the package <gss> (GU, 2014). We classified the data by participant, group (PD or CAS), repetition, word, target phoneme, phone produced, and positions of X and Y pixels relative to the contour of the observed body of the tongue in order to carry out the analyses. We fit one SSNOVA model for each correct and incorrect production of each phoneme, and used the predicted tongue contours to compare the PD and CAS groups.

### 3 RESULTS

#### 3.1 PERCEPTUAL AND ARTICULATORY ANALYSES

The perceptual analysis of the consonants /t/ and /k/ of children with PD and CAS is shown in Table 2. The agreement of at least 2 judges was considered for each repetition. If judge 1 analyzed the sound stimulus as [t], judge 2 as [k] and judge 3 as [t], the validated answer in this analysis was [t].

From the total of 15 productions of /t/ by children with PD, 6 were evaluated as correct productions [t], 3 were judged as [k], and 6 as [p]. Regarding the 15 productions of /t/ by the children with CAS, 12 were evaluated as correct productions [t], 1 was evaluated as [p], and 2 as [d]. Concerning the 15 occurrences of /k/ produced by the children with PD, a total of 6 were evaluated as correct productions [k], 6 were judged as [t], and 3 as [p]. In the CAS group, from the 15 productions analyzed, 9 were evaluated as correct [k], and 6 as [t].

The productions evaluated by the judges as [p] were excluded from the articulatory analysis since lip movements are not detected by the ultrasound images. The production of /t/ → [k] was made by only one child, and, therefore, was not included in the articulatory analysis since there would be no other contour to compare it with (Table 2).

	<b>Clinical Conditional</b>	<b>Correct Plosive productions</b>	<b>Plosive Substitutions</b>
<b>Child 1</b>	PD	/k/ → [k] (3/3)	/t/ → [k] (3/3)
<b>Child 2</b>	PD		/t/ → [p] (3/3) /k/ → [t] (3/3)
<b>Child 3</b>	PD	/t/ → [t] (3/3)	/k/ → [p] (3/3)
<b>Child 4</b>	PD	/t/ → [t] (3/3) /k/ → [k] (3/3)	

Child 5	PD		/t/ → [p] (3/3) /k/ → [t] (3/3)
Child 6	CAS	/t/ → [t] (1/3)	/t/ → [p] (1/3) /t/ → [d] (1/3) /k/ → [t] (1/3)
Child 7	CAS	/t/ → [t] (2/3) /k/ → [k] (3/3)	/t/ → [d] (1/3)
Child 8	CAS	/t/ → [t] (3/3) /k/ → [k] (3/3)	
Child 9	CAS	/t/ → [t] (3/3) /k/ → [k] (3/3)	
Child 10	CAS	/t/ → [t] (3/3)	/k/ → [t] (3/3)

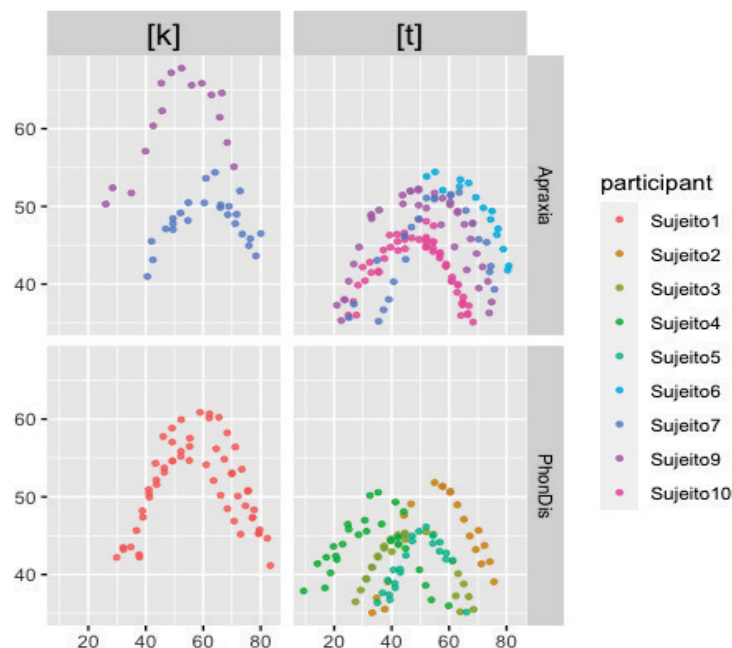
**Table 2:** Auditory-perceptual analysis for the children with PD and with CAS

Source: Authors

### 3.2 ARTICULATORY ANALYSIS

The productions of both groups (PD and CAS) will be presented as correct (/t/ → [t] and /k/ → [k]) and then incorrect /k/ → [t]. The SSANOVA results of the tongue movements were analyzed from anterior tongue (AT) and posterior tongue (PT). Figure 2 presents individual x and y coordinates of all productions of [t] and [k] by group and color-coded by participant.

Those data were used to fit the SSANOVAs. The anterior part of the tongue is on the left of the tongue contours, the body is in the middle, and the posterior part is on the right (Figure 2).



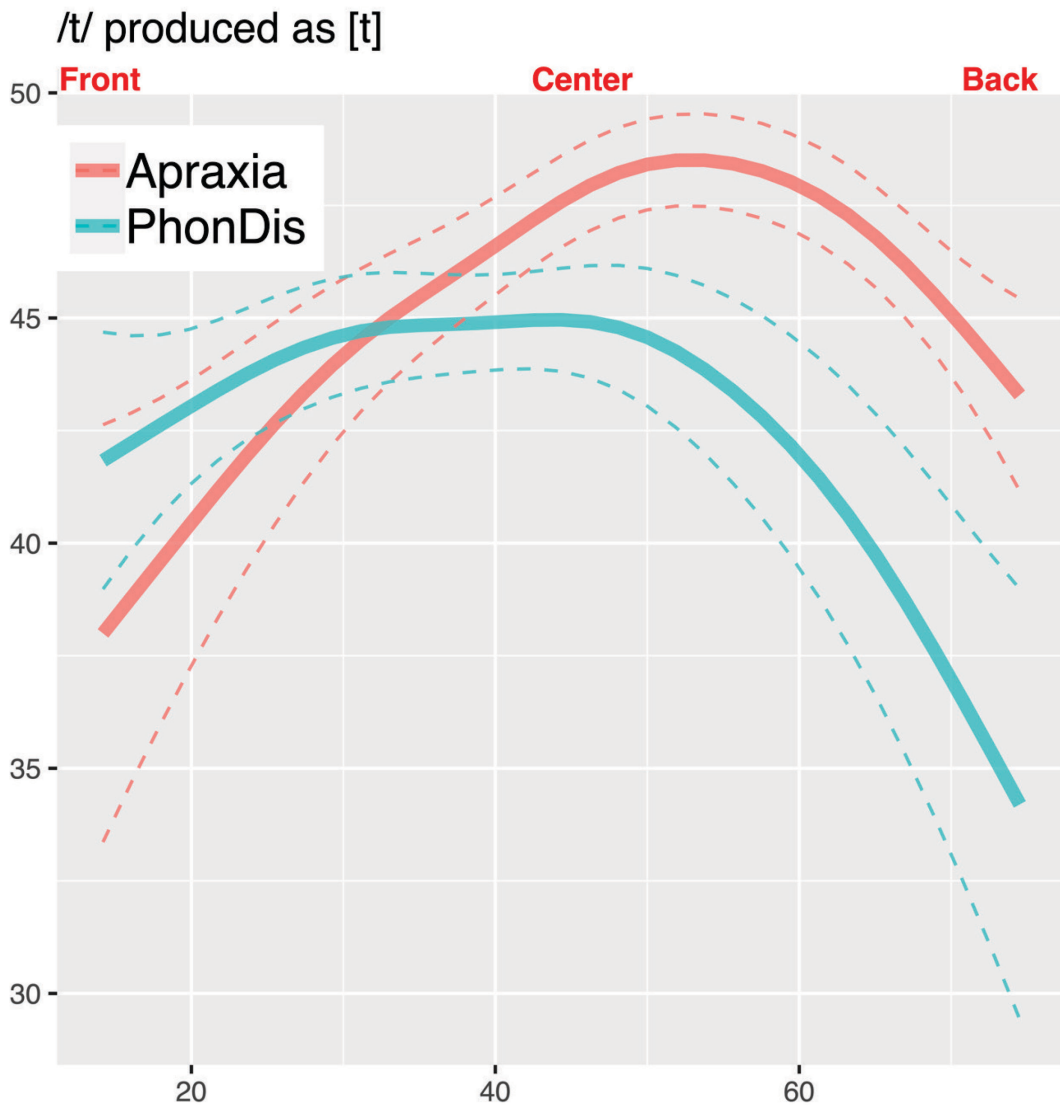
**Figure 2:** SSANOVA plot of all productions of [t] and [k] by clinical group.

Source: Authors

## 3.3 PERCEPTUALLY CORRECT PRODUCTIONS

**/t/ produced as [t]: children (3 and 4 - PD) and children (6, 7, 8, 9 and 10 - CAS):**

The individual data points in figure 2 show a lot of variability within groups and within participants. One of the purposes of the SSAnova is to model average tongue contours based on the values obtained from participants, so groups can be compared by the average tongue contours predicted by the model. Some predicted tongue contours are shown regarding both groups in figure 3, with 95% confidence intervals represented by the dashed lines:



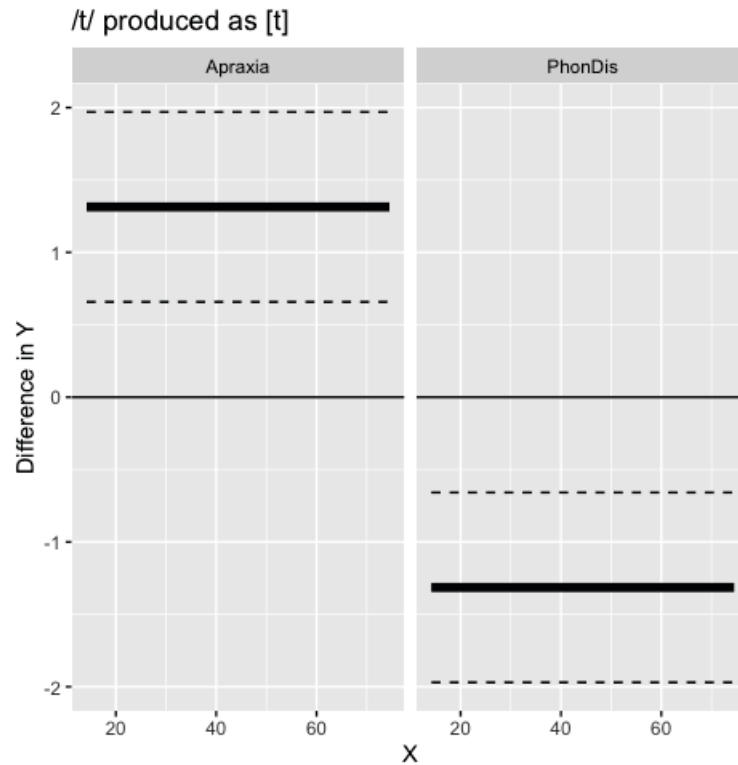
**Figure 3:** SSANOVA prediction of tongue contours for /t/ produced as [t] both groups

Source: Authors

As can be seen, the production of [t] when the target sound was /t/ by children with CAS shows that the tongue tends to increase subtly in the posterior region but does not have elevation of the anterior part. Children with PD have an abrupt lowering of the posterior part of the tongue, with the anterior part also showing an abrupt lowering, with a slight elevation towards the beginning of the central part.

Next, the difference in the  $y$  values was analyzed when only 'group' is used to predict it, excluding the *intercept* and  $x$  terms. The result is shown in Figure 4:





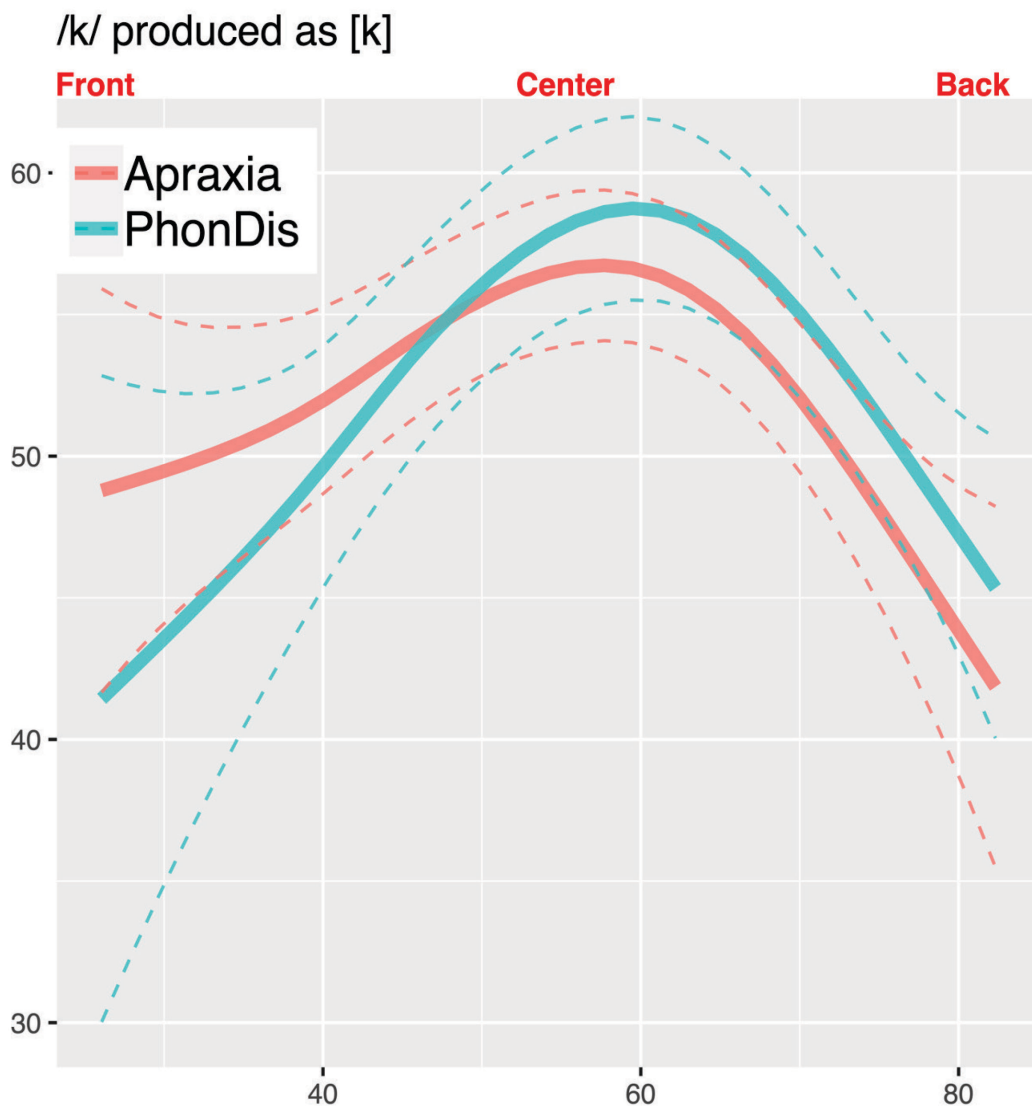
**Figure 4:** Difference in y values between the CAS and PD groups for /t/ produced as [t]

**Source:** Authors

The dashed lines represent 95% confidence intervals around each group's effect, and the fact that they do not cross zero shows that there is a significant effect of 'group'.

**/k/ → [k]: children (1 and 4 - PD) and children (7, 8 and 9 - CAS):**

The same procedures were used for /k/ produced as [k]. The resulting contours predicted by the SSANOVA are shown in Figure 5. The production of [k] by children with PD has the posterior part of tongue elevated and the anterior part lowered, while children with CAS had a tongue contour similar to the group of children with PD, but with a lower magnitude.

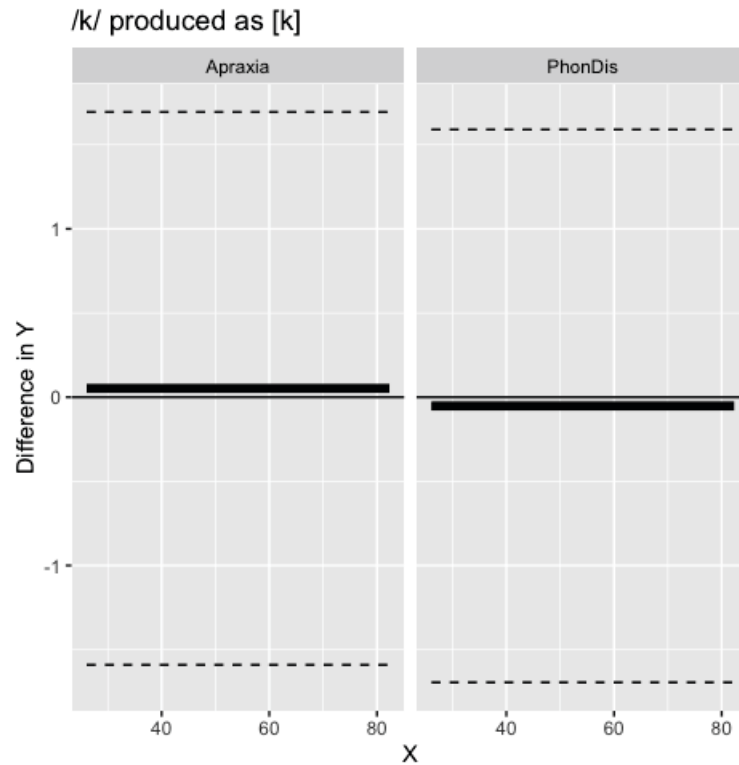


**Figure 5:** SSANOVA prediction of tongue contours for all productions of /k/ produced as [k] by both groups

**Source:** Authors

The production of [k] for the group of children with CAS shows that the tongue tends to subtly elevate in the anterior part, raising the body and lowering the posterior part of the tongue, while children with PD have a similar tongue contour behavior, but with less magnitude in the anterior part of tongue, whereas the body and posterior parts are greater than in CAS.

The contours of the two groups were very similar, with the 95% confidence intervals (areas within dashed lines) overlapping for the most part. The differences in  $y$ , which were both virtually zero, are shown in Figure 6:



**Figure 6:** Difference in y values between the CAS and PD for /k/ produced as [k]

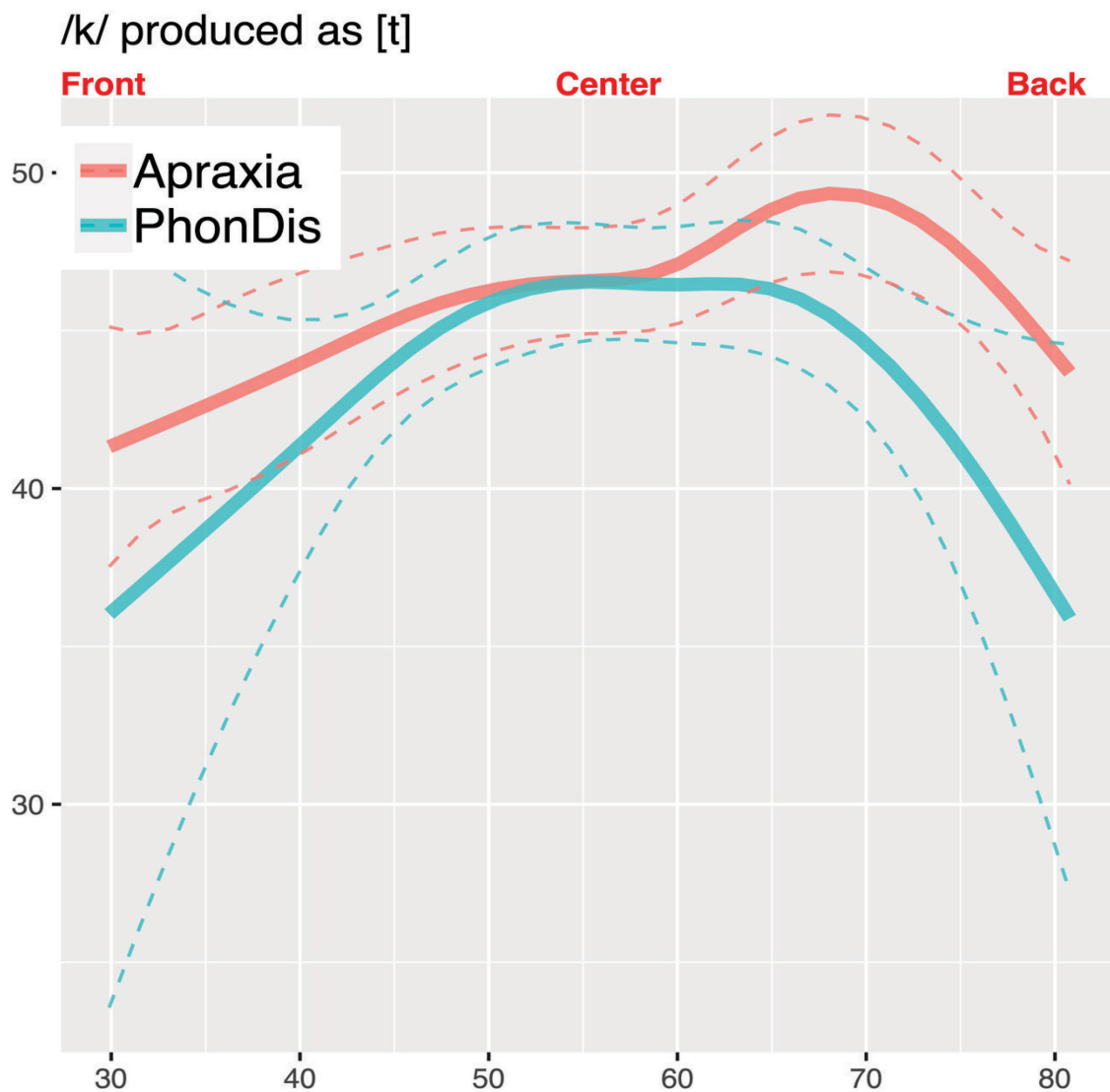
Source: Authors

The difference in y did not have an effect of 'group', since the confidence intervals did cross zero, as can be seen in figure 7. Therefore, an effect of 'group' cannot be inferred in this comparison.

### 3.4 PERCEPTUAL SUBSTITUTION

**/k/ → [t]: children (2 and 5 - PD) and children (6 and 10 - CAS):**

Four participants produced [t] when the target was /k/ (frontalizing) and the tongue contours predicted by the model are shown in Figure 7.

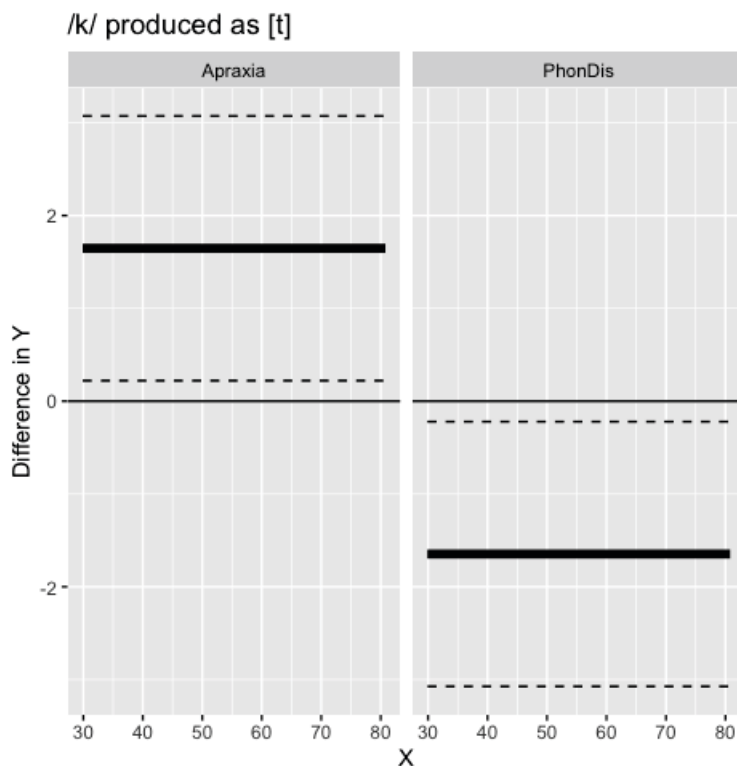


**Figure 7:** SSANOVA prediction of tongue contours for all productions of /k/ produced as [t] by both groups

Source: Authors

The production of [t] (when the target was /k/) for the group of children with CAS has the anterior part of tongue lowered and body and posterior parts of tongue elevated. Children with PD also have the anterior part of the tongue lowered, but the body of the tongue increased.

The differences in y values of the clinical groups can be seen in Figure 8.



**Figure 8:** Difference between the CAS and the PD (/k/ produced as [t])

Source: Own elaboration

The dashed lines represent 95% confidence intervals around each group's effect, and the fact that they do not cross zero show that there is a significant effect of 'group'.

#### 4 DISCUSSION

This study aimed at comparing the tongue contours of children with PD and CAS in the speech production of two plosives in Brazilian Portuguese. The hypothesis that the tongue contours of children with PD would be different from those with CAS in Brazilian Portuguese was partially confirmed.

When comparing the two clinical groups, PD and CAS, the SSANOVA was significant only for productions of [t], that is, in the correct productions of /t/ as [t] and in the incorrect productions of /k/ as [t]. The groups were not significantly different when producing /k/. The tongue contours were detected in an expected region for the target sound, that is, [t] produced with greater elevation of the anterior part of tongue for the group with CAS, while children with PD had greater constriction in the body of the tongue for [k].

To achieve the production of plosives, speakers must close the passage of air completely with the articulators and maintain this closure for its subsequent release (STEVENS, 2000). Through acoustic analysis, Cristofolini and Seara (2012) analyzed the production of plosives by Brazilian children and identified that, to reach the target, they needed to improve motor skills of the speech production (closure and release), both temporally and in terms of magnitude.

Although children from both groups were able to produce plosives appropriate to the targets, there were significant articulatory differences between the groups in the alveolar plosive. This means that, to reach the target, the children in each group, PD and CAS, used different articulation strategies, as can be seen when visually analyzing the contours predicted by the SSANOVA and when analyzing the group effect on the y values.

In the case of fronting of velar plosives, the SSANOVA also showed a statistical difference between the clinical groups. A previous study (MELO *et al.* 2017), also carried out with Brazilian children, identified in ultrasound images that groups of children with PD have a decrease in the constriction of the posterior region of the tongue during the production of velar plosives, corroborating the data of this study for both PD and CAS (/k/ produced as [k]) since there was no statistical difference between the clinical groups.

Another study (GIBBON, 1999) involving the analysis of speech production of English children with PD through electropalatography (EPG) showed that there is a higher tongue position against the palate for fronting of velar plosives. The authors interpreted this articulatory strategy as a failure in the dissociation of different parts of the tongue. Thus, there was an elevation of the back of tongue and a reduction of the tip of the tongue, which result in an undifferentiated gesture (UG) and, consequently, in a higher position of the tongue against palate (without differentiation between the parts). The data from this study confirm the presence of UG in the production of velar plosives by children with PD.

The fronting of velar plosives (/k/ produced as [t]) is associated with difficulties in the control of the tongue, since, to produce velar phonemes, different movements of the tongue and jaw are necessary, as well as the differentiated control of the anterior and posterior regions (MCALLISTER BYUN, 2012). Thus, as in this study there was a statistical effect in the difference between groups in frontalized productions, it is believed that both groups have difficulties in tongue control, but the group of children with PD may be associated with the presence of UG, while the group of children with CAS would be linked to difficulties of planning and/or programming spatiotemporal parameters of the movement sequences of speech (ASHA, 2007; SHRIBERG *et al.*, 2012).

One limitation of this study is that the sample was too small to draw a complete description of plosives produced by children with CAS and with PD in Brazilian Portuguese. However, the data show indications of different articulation strategies to produce the same target (alveolar plosive). Future research comparing the productions of children with CAS and with PD can contribute to understanding the emergence of alveolar and velar contrasts in disordered speech development and possible differences in motor speech among disorders.

## 5 FINAL REMARKS

This study aimed at comparing the tongue contours of children with PD and with CAS in the speech production of two plosives in Brazilian Portuguese. The results indicated differences in tongue contours between children with PD and CAS for correct and incorrect productions of [t] (/t/ → [t] and /k/ → [t]). Children with PD showed different articulatory gestures in correct and incorrect productions when compared to children in CAS.

In future studies it is necessary to include a greater number of participants from both groups (PD and CAS) in order to investigate the refinement of articulatory gestures in atypical language and/or speech development. It will contribute to the understanding of how atypical children learn from phonemic contrast of different sounds of Brazilian Portuguese.

## ACKNOWLEDGEMENT

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