

Description of the articulatory gestures concerned in the production of the sounds /r/ and /l/

Descrição dos gestos articulatórios envolvidos na produção dos sons /r/ e /l/

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ABSTRACT

Purpose: Analyze the data of the nature articulatory of liquid consonants and the coarticulation of different contexts vowel production with the use of ultrasound with a focus on the Gestural Phonology in the speaker typical adults from the Brazilian Portuguese. **Methods:** Participated in the survey five adults, aged 25 and 37 years. Three pairs of words were selected with the sounds /r/ and /l/, in Onset Medial, in different vowel contexts: /a/, /i/, /u/. The recordings of tongue images were made with the Portable Ultrasound Model DP- 6600. All the words were represented in images included in the same vehicle sentence. The articulatory gestures were captured by the ultrasound and analyzed by AAA software (Articulate Assistant Advanced). The images of articulatory gestures viewed in ultrasound corresponded of frames to the maximum elevation of the tongue tip in the production of /l/ and /r/. **Results:** /r/ and /l/ have two gestures simultaneous: tip and body of tongue. The vowel /i/ following the /r/ and vowel /u/ following the /l/ showed higher degree of constriction in the tip and body of tongue, respectively. **Conclusion:** The segments researched present doubles gestures of tongue. The coordination of gestures of /r/ and /l/ associated with different vowel contexts reveals different gestural configurations.

Keywords: Speech; Speech acoustics; Ultrasonics; Adult; Speech, language and hearing sciences

RESUMO

Objetivo: Investigar os dados de natureza articulatória de consoantes líquidas e a coarticulação dessas consoantes diante da produção de diferentes contextos vocálicos, em adultos falantes típicos do Português Brasileiro (PB). **Métodos:** Participaram da pesquisa cinco adultos com idades entre 25 e 37 anos. Os gestos articulatórios foram capturados pelo ultrassom Modelo DP-6600 e analisados por meio do *software* AAA (*Articulate Assistant Advanced*). Foram selecionados três pares de palavras com os sons /r/ e /l/, em *Onset Medial*, em diferentes contextos vocálicos: /a/, /i/, /u/. Todas as palavras foram representadas por figuras, incluídas em uma mesma frase veículo. As imagens dos gestos articulatórios visualizadas no ultrassom corresponderam aos *frames* relativos à elevação máxima da ponta da língua nas produções de /r/ e /l/. **Resultados:** /r/ e /l/ apresentaram dois gestos simultâneos: ponta e corpo da língua. A vogal /i/, em contexto seguinte ao /r/, e a vogal /u/, em contexto seguinte ao /l/, proporcionaram maior grau de constricção da ponta e do corpo da língua, respectivamente. **Conclusão:** Os segmentos pesquisados apresentaram duplos gestos de língua. A coordenação dos gestos de /r/ e /l/, associados aos diferentes contextos vocálicos, revelou diferentes configurações.

Descritores: Fala; Acústica da fala; Ultrassom; Adulto; Fonoaudiologia

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INTRODUCTION

Speech production requires complex coordination, involving organization, planning and execution of phonoarticulatory movements. Technological advances have enabled the use of more sophisticated techniques of speech analysis, mainly of acoustic nature. As a result, it was possible to see, in the speech signal, facts hitherto undocumented, which meant that the available models of phonological analysis had to be reconsidered, including the relationship between phonetics and phonology⁽¹⁾. The dynamic models of speech production are a result of these reflections, whose main exponent is the Gestural Phonology⁽²⁾.

The new paradigm has been encouraged, on the one hand, by studies that, arisen under the inspiration of Cognitive Linguistics, explore primarily the concepts of dynamics and on the other, by studies that, immersed in Cognitive Science, explore primarily their tools⁽³⁾.

In using these tools, the acoustic analysis allows us to observe the phonetic detail that is often essential for understanding phonic facts, which otherwise would remain obscure⁽¹⁾. In Brazilian Portuguese, studies using acoustic analysis in studies of speech and which strengthened reflections on the theoretical models that supported these analyzes stand out^(4,5). Articulatory and acoustic analysis tools provide robust empirical evidence to assert that the linguistic phonetic detail must be represented in the grammar of that language⁽⁴⁾.

Combined with acoustic analysis, analysis of articulatory gestures is highlighted departing from an important tool: the ultrasound of language movement. Software capable of synchronizing sound and articulation signs, made the research in the area possible. However, the incorporation of data of articulatory nature from the ultrasound data in light of a dynamic model of speech production is a recent practice in Brazil⁽⁶⁾.

Ultrasound also offers advantages such as not having risks to health and being relatively inexpensive when compared to other imaging methods. In speech analysis, this equipment is successfully employed to monitor tongue movements, providing images of its outline⁽⁷⁾.

In the perspective of Gestural phonology, the phonological structure of the language can be described in a set of articulatory gestures. It is worth noting that the term “articulatory gesture,” primitive unit of analysis in this perspective, refers both to an action of constriction of the different articulators, and the representation of this articulatory maneuver, required for this action to occur.

Studies show⁽⁸⁾ that the liquid consonants belong to the latest acquisition class in typical speech development and are the most difficult for children with disorders in speech sounds. There is need for studies that contribute to the characterization of these segments, ie, the hypothesis that the production of these sounds would involve the coordination of two simultaneous gestures, in the analyzed subjects.

In American English, the liquid /r/ and /l/ are described with two different language gestures, in image analyzes⁽⁹⁾. These sounds are rather complex because they involve anatomically coupled articulators - in this case, the tongue - with double gestures, tip and tongue body simultaneously. It is important to highlight that the alveolar tap [ɾ] is an extraordinarily complex segment, having different supralaryngeal constrictions⁽¹⁰⁾.

From these considerations, the characterization of typical speech becomes essential for the BP, specifically the finding of simultaneous gestures in the production of liquid consonants, with the use of ultrasound. The characterization of stable production patterns in adults will collaborate in studies on the complexity of the acquisition of these segments and in the research on the speech errors involving them.

The aim of this study was to investigate the data of articulatory nature of liquid consonants and the coarticulation of these consonants, before the production of different vocalic contexts, in typical adults speakers of Brazilian Portuguese (BP).

METHODS

The study included five typical adult speakers of BP, one male and four females, aged 25 to 37 years, average age 30 years, all speech therapists students of a post-graduation course at doctorate level. The participants signed the Informed Consent (IC), as required by the Ethics Committee of the Universidade Federal de Santa Maria (UFSM), which approved the study protocol under the no 442.786.

This is a descriptive and retrospective study, with a sample defined by convenience. The study subjects were volunteers and agreed to the conduction of evaluations after prior and detailed explanation of the procedures.

All the typical speakers analyzed had the characteristics of the variant spoken in central Rio Grande do Sul. The speech of this region presents the production of weak-r as alveolar tap [ɾ].

All subjects met the criteria for inclusion of speech therapy evaluations (audiological, orofacial motricity, comprehensive and expressive language and voice) within the normal range.

Data collection was performed at the Speech Therapy Service (STS) of a higher education institution. The collection time of ultrasound images for each subject varied between 20 and 40 minutes, being held in a single session.

The recordings of tongue images were made individually, with unidirectional microphone, portable ultrasound, DP 6600 model, with micro-convex transducer coupled to a computer. The image signals were captured and analyzed using the *Articulate Assistant Advanced* software (AAA)⁽¹¹⁾.

The corpus used in the recordings was consisted of six words represented in images in the segments /r/ and /l/, in the vocalic contexts /a/ preceding and following in [barata] and [salada]; /a/ and /e/ preceding and /u/ following in [charuto] and [cabeludo] and finally, /e/ and /a/ preceding and /i/ following

in [ferida] and [falida]. It was requested from each subject, six replications of each word inserted in vehicle phrase (“say xxx again”) (Chart 1).

Chart 1. Following vocalic context and respective selected words

Vocalic Context	High Sound	Words
/a/	/r/	[barata]
	/l/	[salada]
/i/	/r/	[ferida]
	/l/	[falida]
/u/	/r/	[charuto]
	/l/	[cabeludo]

The AAA program presents an image on the computer screen, corresponding to the word which the subject must produce and has an audible indicator that warns about the start of the recording and, therefore, the beginning of the speech production. All participants received prior verbal training on the repetition of the vehicle phrase corresponding to every figure. Thus, each vehicle phrase containing the target word was repeated six times.

The participants named the figures inserted in the vehicle phrase quoted. The nominations always followed the same order of presentation, according to the list: barata, salad, charuto, cabeludo, ferida, and falida. The sequence of presentation of the figures was maintained until the conclusion of the six repetitions for each word.

The analyses of yields were obtained in a single collection. In order to meet the criteria as to stabilization of head and comfort during the collection, head stabilizer was used⁽¹¹⁾, ensuring greater reliability on the data obtained. This stabilizer is a helmet built of aluminum and weighs 800 grams. It is adjustable at several points and allows the stabilization of the sensor (probe) used to capture the images and which is placed under the chin. The helmet, when stabilizing the probe in the submandibular region, allows the reduction of variation of head movement in image capture and layout of the tongue.

After the collection, the moments (frames) corresponding to the segments /r/ and /l/ were analyzed, being chosen the one in which there was a maximum elevation of the tongue tip, supposedly representing the arrival at the target. A layout was conducted under the surface of the tongue, in sagittal section, in the self-extraction.

The analysis of frames corresponding to the maximum elevation of the tongue was performed by three speech therapists with experience in the area of speech and in the use of the program used in the collection, being the moment of maximum tongue tip elevation in each production a consensus among them, for all subjects.

The tongue images were selected from the previously

described *frame* in each segment /r/ and /l/ on the corresponding words. For each image, a layout of the tongue outline was made. Thus, for each subject six layouts were obtained for the six repetitions of the same word. The AAA program allows the averaging of these tongue layouts and the average corresponded to a single tongue outline referring to the production of each word, by each of the subjects.

The means of the tongue outlines corresponding to the production of each of the five subjects were included in graphs which demonstrate the articulatory gestures analyzed.

In the classification of gestures, the descriptors used were those proposed by Gestural Phonology (FonGest), having the tract variables specified which correspond to the constriction actions of the organs of the vocal tract and their reference with the articulators involved^(2,12). In the classification of gestures, there was also consensus among three speech therapists with experience in the speech area.

Below, the tract variables considered for the qualitative descriptions of the articulatory gestures involved in the production of /r/ and /l/ are indicated:

- 1) Place of tongue tip constriction (LCPL)
- 2) Tongue tip constriction degree (GCPL)
- 3) Oral constrictor guidance
- 4) Place of tongue body constriction (LCCL)
- 5) Tongue body constriction degree (GCCL)

In the description corresponding to /r/ and /l/, the following were considered: tongue tip as an articulator and the respective previous place of constriction, with the guidance of apicolaminal or alveolar articulator. As to the degree of constriction of the articulators, the open (referring to the approximants) and narrow tongue tip were selected as descriptors. Besides the place and degree of constriction, it was considered the number of gestures involved and if they belonged or not to the same oral subsystem.

RESULTS

The means of the tongue surface outlines (in millimeters) of each subject, for the segments /r/ and /l/, in the context of the vowel /a/, obtained in the words [barata] and [salada]; for the segments /r/ and /l/, in the following context of the vowel /i/, obtained in the words [ferida] e [falida] and the segments /r/ and /l/ obtained in the following context of the vowel /u/ in the words [charuto] and [cabeludo] are shown in Figure 1.

Figure 2 displays the ultrasound image of the tongue in the precedent and antecedent contexts of the vowel /a/ to /r/ and /l/, in the words [barata] and [salada], respectively.

Figure 3 shows the ultrasound image of the tongue in the antecedent contexts of vowels /e/ and /a/ and following /i/ to /r/ and /l/, in the words [ferida] and [falida], respectively.

Figure 4 displays the ultrasound image of the tongue in the antecedent contexts of vowels /a/ and /e/ and following /u/ to /r/ and /i/, in the words [charuto] and [cabeludo], respectively.

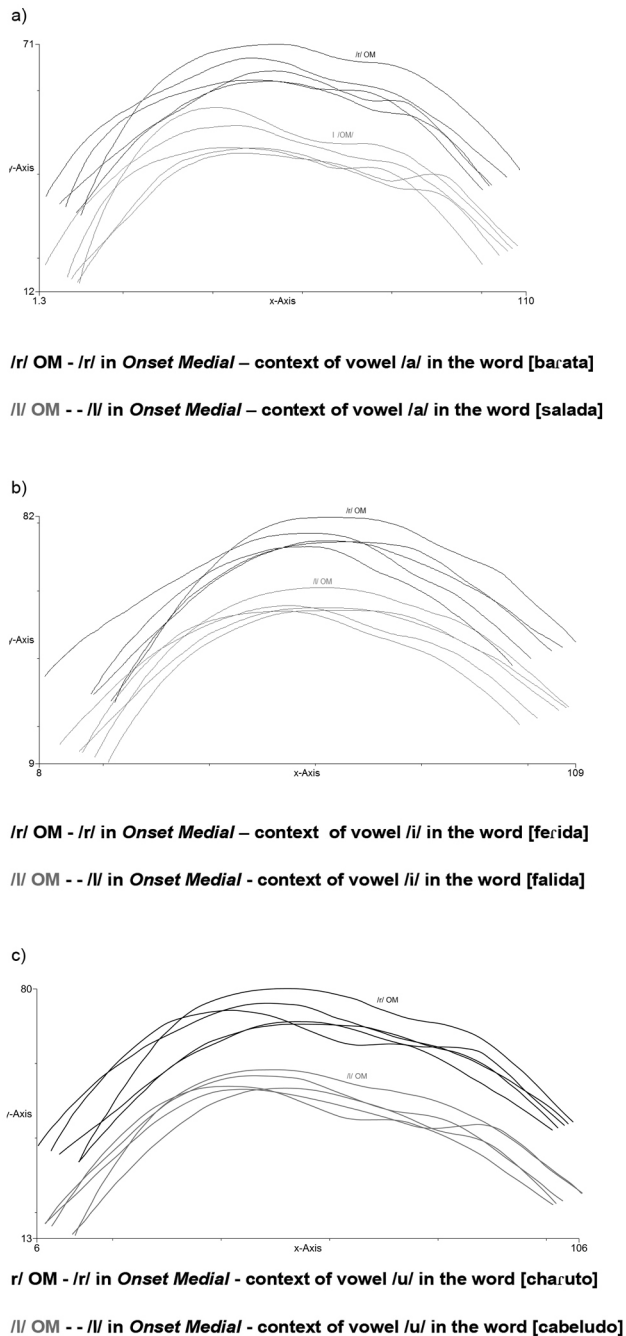


Figure 1. Means of tongue surface outlines (in millimeters) on axis x/y in each of the five subjects

DISCUSSION

The most common instrumental tool applied to aid in the diagnosis and treatment of speech and language is the acoustic analysis, however, this important tool does not allow direct access to aspects of speech production, since it analyzes the acoustic signal resulting of the articulatory movement produced by the individual⁽¹³⁻¹⁵⁾.

The articulatory analysis allows direct visualization of the movements of the articulators, providing more accurate information about the processes involved in speech production⁽¹⁶⁾.

The use of ultrasound in the analysis of tongue movements, combined with a dynamic model of speech production allows not only reinterpret, but also raise explanatory hypotheses about the phonological processes⁽¹⁴⁾.

The ultrasound wave makes it possible to see, clearly, the tongue surface and therefore observe the movements performed to produce a particular sound⁽⁹⁾. Ultrasound allows imaging beyond research and clinical purposes, being an important tool for therapeutic purposes, such as visual *feedback* of articulatory movements⁽¹⁷⁾.

The use of an instrumental methodology makes it possible grasping which, and to what extent, the phonetic-acoustic parameters are being employed to separate the different sounds of speech⁽¹⁸⁾. In this study we analyzed the realization of stable patterns of aspects of the production of liquids in adults, allowing the use of instrumental methodology to obtain parameters for Brazilian Portuguese speakers, which has been little studied.

In the analyzes of tongue movements in adults, performed in this study, the images obtained with the ultrasound probe positioned below the chin, in the sagittal position, made it possible the visualization of the tongue from the root to the tip, which is relevant when analyzing the production of liquids⁽¹⁹⁾ (Figures 2, 3 and 4).

The observation of the articulation pattern in normal adults, made by ultrasound, is of great importance, as it provides information for comparing the variations detected with the ones found in the production of speech of children during development⁽¹⁹⁾. The aspects of speech production of children are slower and unstable, which may be related to aspects of coarticulation⁽²⁰⁾. A study⁽²¹⁾ compared the production of speech of children and adults through typical ultrasound images, noting clearly that children productions have higher variability, pointing, yet, to instability in the realization of gestures.

In this study, in the no-lateral alveolar liquid *tap* [r] and lateral alveolar liquid /l/ two gestures involving the same oral subsystem were found: gestures of tip and body of tongue, produced simultaneously (Figure 1). The gestures might belong to the same oral subsystem and also involve the same tract variables⁽⁶⁾. The hypothesis that the rhotic and the lateral are constituted by two gestures is based on the phonetic similarity between these segments and the processes that they share⁽¹⁾.

This research is a recent and innovative practice in the analysis of articulatory gestures obtained by ultrasound images in the liquids of BP in adults. Previous research in BP, using acoustic analysis, suggest that the liquids have double acoustic-articulatory regions^(1,4,22), strengthening the findings of this article. In the proposal of FonGest, the liquids are formed by a gesture in the coronal region and simultaneously by a gesture at the dorsal pharyngeal region⁽²²⁾.

Recent research⁽¹⁴⁾ identified by ultrasound image of the tongue, the presence of two simultaneous articulatory gestures in the liquids /r/ and /l/ in BP, confirming the method used and the findings of this research. There was presence of double

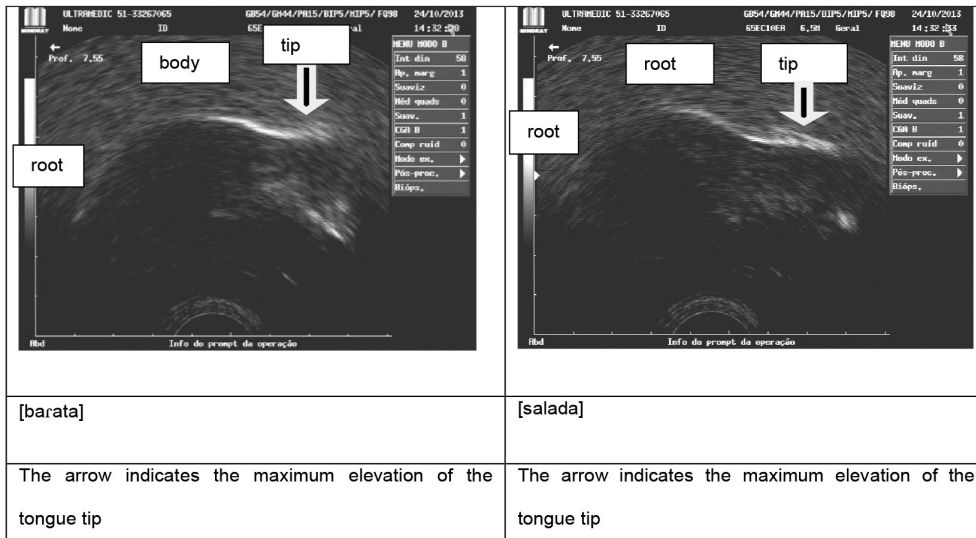


Figure 2. Frame obtained in the maximum elevation of the tongue tip in the /r/ and in the /l/ in the word, in one of the five subjects

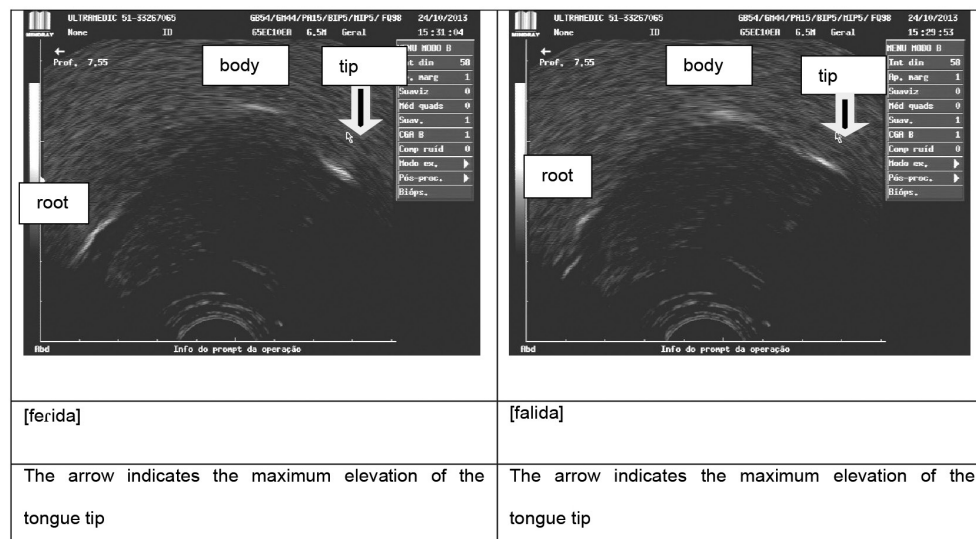


Figure 3. Frame obtained in the maximum elevation of the tongue tip in the /r/ and in the /l/ in the word, in one of the five subjects

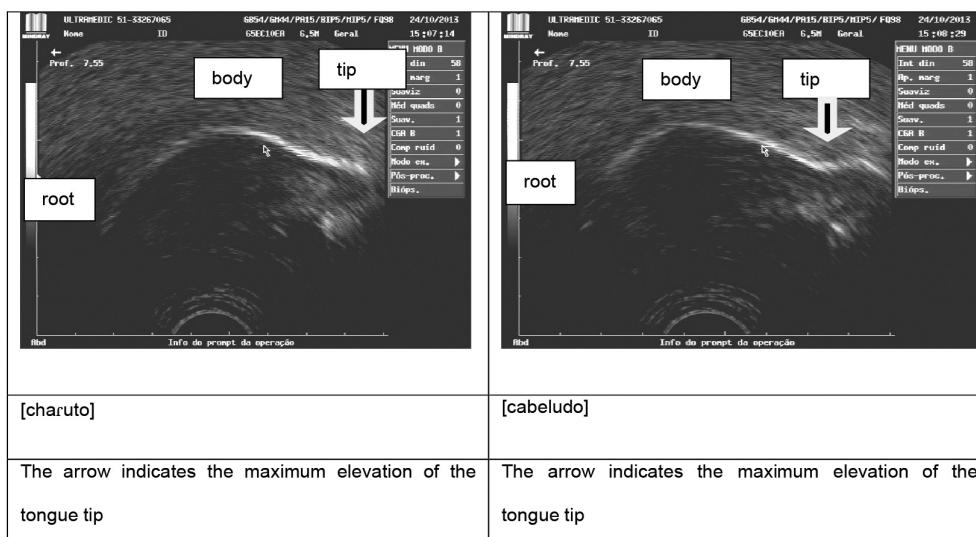


Figure 4. Frame obtained in the maximum elevation of the tongue tip in the /r/ and in the /l/ in the word, in one of the five subjects

gestures in the production of liquids and this fact imposes greater difficulty in coordination of movements⁽¹⁴⁾. This statement suggests that, also for the BP, the acquisition of /r/ and /l/ requires refined and coordinated skills of dissociated and simultaneous movements of the tongue.

A descriptive study⁽⁹⁾ found that the sounds /r/ and /l/ in American English also present two simultaneous distinct gestures of the tongue. The /r/ and /l/ were investigated considering the following contexts of the vowels /i/ and /u/ to /r/ and the vowel /u/ preceding the /l/. The authors suggest that /r/ and /l/ require movements coordination dependent of the same articulator - the tongue (the body and back of the tongue) - and claim that multi lingual constrictions segment will be acquired later.

Other recent studies conducted in English, demonstrate the importance of ultrasound investigation to the movements of the /r/^(23,24), being the ultrasound sensitive in the analysis of this segment, including in the research of different regions, in variants of /r/^(25,26).

In this study, the degree of constriction of the tongue tip was higher in /r/ when compared to the /l/ (Figures 2, 3 and 4), suggesting that the /r/ involves greater complexity of coordination than /l/. The /r/ requires simultaneous coordination between the ballistic movement of the tip of the tongue and the constriction towards the pharynx⁽⁴⁾.

There are larger anatomical limitations for /r/ than for /l/, especially in children, because they have a large tongue and a small pharyngeal cavity. This may prevent or hinder the ability to form multiple palatal and pharyngeal constrictions with the tongue, besides different joints to produce acoustic results similar to adults⁽⁹⁾.

In the analyzes performed in this study, when comparing the different vocalic contexts studied, there was a higher tongue tip constriction in /r/, when the vowel /i/ was found in the following context, and higher tongue body constriction in /l/ when the vowel /u/ is presented in the following context, for all five subjects assessed, revealing variation in the dependent gestures of the vocalic context.

It is observed that the phonetic description processes are modeled as a result of variation in gestural parameters, or in the coordination between gestures⁽⁴⁾. The gesture occurs within the limits of certain edges, allowing the lexicalization of a different standardization in its realization, which elegantly models the linguistic change⁽²²⁾.

In this research, the coordination of movements revealed the overlapping of different vocalic contexts, since a higher Tongue Tip Constriction Degree (GCPL) was observed in the /r/ when vowel /i/, this high and previous, was presented in the following context and higher Tongue Body Constriction Degree (GCCL) was observed in the /l/ when vowel /u/, this high and later, was also found in the following context.

The analyses of this study indicate that the production of /r/ followed by the vowel /i/ provided greater degree of constriction to the tip of the tongue compared to the other vocalic contexts

studied. This shows that the vowel /i/ probably facilitates the production of sound /r/.

A study based on FonGest⁽²⁷⁾ indicates the stressed syllable, preceded by /a/ and followed by /e/ as a facilitating context for the production of /r/. Another study⁽⁸⁾ conducted a survey of the lexical items with /r/ in OM, properly produced by the subjects during their treatments in order to compare the most common linguistic backgrounds. The data showed the vowel /i/ (29.75%) and the vowel /a/ (24.79%), as the most frequent precedent contexts.

In relation to the following context, the study⁽⁸⁾ shows the vowel /a/ as the most frequent, occurring 51.24% in the words produced correctly. However, these results differ from the syllabic context analyzed in this study. Another study⁽²⁸⁾ confirms the findings of this research, since it points the vowel /i/ as a facilitating following context for the acquisition of /r/ in OM.

It is considered that the dynamic approach of FonGest captures, in coordination of gestures of double constriction and the temporal dimension, the variability of rhotics in Portuguese⁽⁴⁾.

The stable speech assessment in adults and the exploration of speech errors in children involving the simultaneous production of two gestures in oral liquid can be obtained from the ultrasound analysis of the tongue movements. This tool proves to be viable and relevant, when combined with quantitative analysis⁽⁹⁾.

It is worth noting that the *frame* chosen in this work was based on the maximum elevation of the tip of the tongue on the images obtained by ultrasound. The aim is to develop future work using the synchronized acoustic analysis to articulatory movements for both the selection(s) frame(s), seeking greater precision in the analysis, and for the analysis of quantitative studies associated with the qualitative.

Quantification methods are being studied and developed for the application and will be used in future work⁽⁹⁾. The instruments used for the analysis of articulatory gestures prove to be increasingly sensitive to the exploration of tongue movements. However, there are still technical limitations that have hindered simultaneous studies of supralaryngeal gestures⁽¹⁰⁾.

The analysis of gestures involving different vocalic contexts in the study of consonant segments of the BP in typical adults may be an important reference to the research on the acquisition language by children.

Ultrasonography proved to be an important analytical tool of articulatory gestures of the tongue. This analysis becomes enlightening for studies of speech when one understands the dynamics of movement in the light of Gestural Phonology.

CONCLUSION

From stable production of typical adult speakers of BP investigated in this study, considering the ultrasound evaluations in the analyzed moments, we conclude that the gestural coordination of /r/ and /l/, associated with the different vocalic

contexts, reveals different configurations tip and body of the tongue.

The coordination of movements of /r/ and /l/ associated with different vocalic contexts reveals different gestural configurations. The phonetic detail processes are modeled as a result of variation in the coordination of the gestures.

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