Original Article

Artigo Original

Phonetic description of alveolar phones using electropalatography

Descrição fonética eletropalatográfica de fones alveolares

Marisa de Sousa Viana Jesus[1]
Cesar Reis[2]

Keywords

Phonetics
Speech
Tongue
Palate
Evaluation

ABSTRACT

Purpose: To describe the articulation of the Brazilian Portuguese, by examining the tongue-palate contact in the production of consonantal phones. **Methods:** The electropalatography (EPG) of the alveolar consonants of the Brazilian Portuguese produced by an individual with typical speech was used, considering the alveolar, post-alveolar, palatal, and velar rates, as well as the percentage of activated contacts at the point of maximum constriction, and the visual inspection of palatograms. **Results:** As expected, it was observed that all the examined phones have more contact in the alveolar region at the point of maximum constriction. The phones /t/, /d/ and /n/ showed more alveolar contact, with total obstruction of the air stream; the fricative phones /s/ and /z/ were characterized by the absence of contact at the central longitudinal axis; the lateral phone /l/ did not present contact at the lateral longitudinal axis, and the tap /ɾ/ showed not only few tongue-palate contacts but it was also produced in the shortest duration time. **Conclusion:** The electopalatography allowed a detailed description of the extension of the tongue-palate contact in the different alveolar phones of the Brazilian Portuguese and how they occur.

Descritores

Fonética
Fala
Língua
Palato
Avaliação

RESUMO

Objetivo: Realizar a descrição articulatória do Português Brasileiro, examinando-se o contato da língua com o palato na produção de fones consonantais. **Métodos:** Foi utilizada a eletropalatografia (EPG) de consoantes alveolares do Português Brasileiro de um sujeito com fala típica, considerando-se o índice alveolar, pós-alveolar, palatal e velar e a porcentagem de contatos ativados no ponto de máxima constrição, assim como a inspeção visual dos palatogramas. **Resultados:** Observou-se, conforme o esperado, que todos os fones avaliados têm, no ponto de máxima constrição, maior contato na região alveolar. Os fones /t/, /d/ e /n/ foram os que apresentaram maior contato alveolar, com obstrução total da corrente aérea; os fones fricativos /s/ e /z/ caracterizaram-se pela ausência de contato no eixo longitudinal central; o fone lateral /l/ não apresentou contato no eixo longitudinal lateral e o tapa, /ɾ/, apresentou poucos contatos da língua com o palato e foi produzido com o menor tempo de duração. **Conclusão:** Por meio da eletropalatografia, pode-se fazer uma descrição detalhada da forma e da extensão do contato língua-palato nos diferentes fones alveolares do Português.

Correspondence address:
Marisa S. Viana Jesus
Laboratório de Fonética
Av. Presidente Antônio Carlos, 6627, Campus Pampulha, Belo Horizonte (MG), Brasil, CEP: 31270-901.
E-mail: fono.marisaviana@gmail.com

Received: 9/17/2011

Accepted: 6/12/2012

Study developed at the Phonetics Laboratory, School of Languages and Literature, Universidade Federal de Minas Gerais – UFMG – Belo Horizonte (MG), Brazil.
(1) Graduate Program in Linguistic Studies, School of Languages and Literature, Universidade Federal de Minas Gerais – UFMG – Belo Horizonte (MG), Brazil; Undergraduate Program in Speech-Language Pathology and Audiology, Centro Universitário Metodista Izabela Hendrix – Belo Horizonte (MG), Brazil.
(2) Undergraduate Program in Languages and Literature and Graduate Program in Linguistic Studies, School of Languages and Literature, Universidade Federal de Minas Gerais – UFMG – Belo Horizonte (MG), Brazil.
Conflict of interests: None

INTRODUCTION

The speech results from the action of an articulatory mechanism that involves fast and coordinated movements of several organs that constitute the vocal tract. These organs influence the airflow through the vocal tract, causing flow and pressure variations. The interest in studying the way humans produce speech sounds is ancient. In the beginning, the search was for describing how phones were produced through tactile and visual observation of the articulators' movement. Such observation enabled a reasonable classification of different studied languages.

The palatography is a registration technique of the articulators in the speech output. It was developed in the XIX century, with the experimental phonetics. It registered the contact of the tongue with the palatal region by using different substances, such as olive oil mixed with crushed coal. Some researches of Portuguese phones have been developed using this technique, with the focus on alveolar, palatal and velar consonants[1,2].

The development of instrumental phonetics and, later, of informatics, allowed speech production simulation, and made available to researchers from different areas of knowledge sophisticated descriptions and pictures of the behavior of its production mechanism. The description of these phones by using electropalatography (EPG) has been used as a resource to detailed descriptions of speech[3]. This instrument shows, in real time, spatial and temporal information of the tongue-palate contact. Data are displayed as images that represent the contact of the tongue on the palate, the palatogram, together with numerical indexes that inform the percentage of contacts registered for that phone.

The alveolar phones are particularly favored by the electropalatography study because they are produced in an easily registered contact area of the tongue-palate. They constitute 37% of the consonantal phonemes of Brazilian Portuguese, and are the most productive place of articulation in all languages. The alveolar phones are the ones produced by the contact or proximity of the blade or apex of the tongue with the alveolar region of the palate[4]. As there are many phones produced in the same place of articulation, it is necessary to distinguish them in other aspects to enable the necessary perceptive contrast for the communication process.

In this place of articulation, phones are produced in different manners: occlusive – /t/ and /d/; fricative – /s/ and /z/; lateral – /l/; tap – /ɾ/; and nasal – /n/. Both voiced and voiceless segments are found in this group. Therefore, the alveolar phones constitute a group of major representativeness of the articulatory characteristics of consonantal segments of the Portuguese language.

The aim of this study was to describe the alveolar phones of Brazilian Portuguese, variety of Belo Horizonte (MG), using electropalatography. It is an articulatory study focusing Portuguese consonants produced by a native speaker without speech disorders. It adopts objective techniques, such as electropalatography, and is justified by the possibility of incorporating speech technologies for phonetic characterizations of both typical and atypical speech, for future use in speech-language pathology clinics.

METHODS

This study has been approved by the Research Ethics Committee of Universidade Federal de Minas Gerais, under number 548/09. The speaker involved signed the free and informed consent.

Data were obtained from an adult Brazilian Portuguese speaker, native of Belo Horizonte (capital of the state of Minas Gerais, Brazil), who presented typical speech, with normal occlusion and no history of hearing or speech difficulties.

Speech collection and analysis

Data concerning the tongue-palate contact was obtained by using electropalatography – *WinEPG* (developed by Allan Wrench) with simultaneous acoustic data recorded at 10 kHz. The configuration of the tongue-palate contact was recorded at each 10 ms of each speech sequence, by using an artificial acrylic palate, orthodontic type, with 1.5 ml of thickness and equipped with 62 electrodes. These electrodes are sensible to the contact of the tongue, and registered them in the computer screen enabling a spatial representation of the articulation of different phones on time. The electrodes are organized in the artificial palate in eight lines and columns (Figure 1), the first two lines in the anterior posterior direction were considered as alveolar (LA1 and LA2), and, in the sequence, every two lines, as post-alveolar (LPA1 and LPA2), palatal (LP1 and LP2) and velar (LV1 and LV2). All regions present 16 electrodes, except the alveolar region, which has 14 electrodes, each square corresponding to an electrode. As for the eight columns organized in the longitudinal axis, the two in each side of the palate were characterized as right and left, and the four in the middle, as central. In the palatogram, the areas considered in the analysis are the ones in black, corresponding to 60% to 100% of contact in the established period.

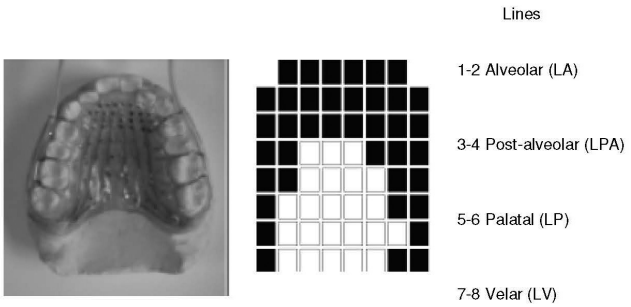

Figure 1. Artificial palate showing the 62 electrodes. To the right, the palatogram of the alveolar phone [t], demonstrating the regions of possible contact between tongue and palate, black squares show effective contact and white ones non effective.

The alveolar phones /s/, /z/, /t/, /d/, /n/, /l/ and /ɾ/ followed by the vowel /a/ in stressed syllables in the middle of words were analyzed. To do so, the speaker pronounced three times, in normal speed, random order, the following list of words in Portuguese: *massada, casada, batata, fadada, sanada, falada e parara*. The option of choosing a single vowel was to minimize the articulation effect of the vowel upon the consonant. The

speaker, who is one of the researchers, had previous experience in using the artificial palate. Due to this, the corpus recording happened naturally.

The analysis consisted on the exam of contact patterns of tongue-palate for each alveolar phonemic target. In this procedure we adopted the Articulate Instruments program, which displays different contact indexes. We adopted the following indexes: total alveolar, total post-alveolar, total palatal and total velar, since they provide all together information about all the activated contacts during the production of each phone.

Each index represents the rate of electrodes distributed on the palatogram activated by the contact of the tongue in a specific palate or alveolar region. Thereby, for example if there were eight contacts in the post-alveolar region, the post-alveolar index is equal to 0.5, as eight of the 16 electrodes have been activated by the tongue contact. We also calculated the contact percentage (CP) in the maximum constriction point of each phone, by taking into consideration the total number of activated electrodes divided by 62, and the result multiplied by 100[5].

In this study, three points were selected for the duration of the phone, which represented its articulation dynamics. Each point have the duration of 20 ms. The first point begins at the end of the vowel F1 that precedes the studied phone. The second one is measured 20 ms in the middle of the duration of the phone. The third one is measured after 20 ms of the studied phone, measured from the beginning of the vowel F1 that follows. The central point is situated in the most stable and under the highest constriction point of the phone.

For each selected point, the total alveolar, total post-alveolar, total palatal and total velar indexes displayed by the program were obtained. For the maximum constriction point the CP was also used. For the tap [ɾ], indexes were obtained only at the point of maximum constriction, due to its short duration.

RESULTS

The electropalatography, since it is an instrumental technique that detects and visually displays the tongue contact with the palate during speech in real time, enables a spatial and temporal vision of the articulatory production of alveolar phones. Specific characteristics of each phone were presented considering the phone formation (Figure 2) and the characteristics of the phone in the maximum constriction point (Figure 3).

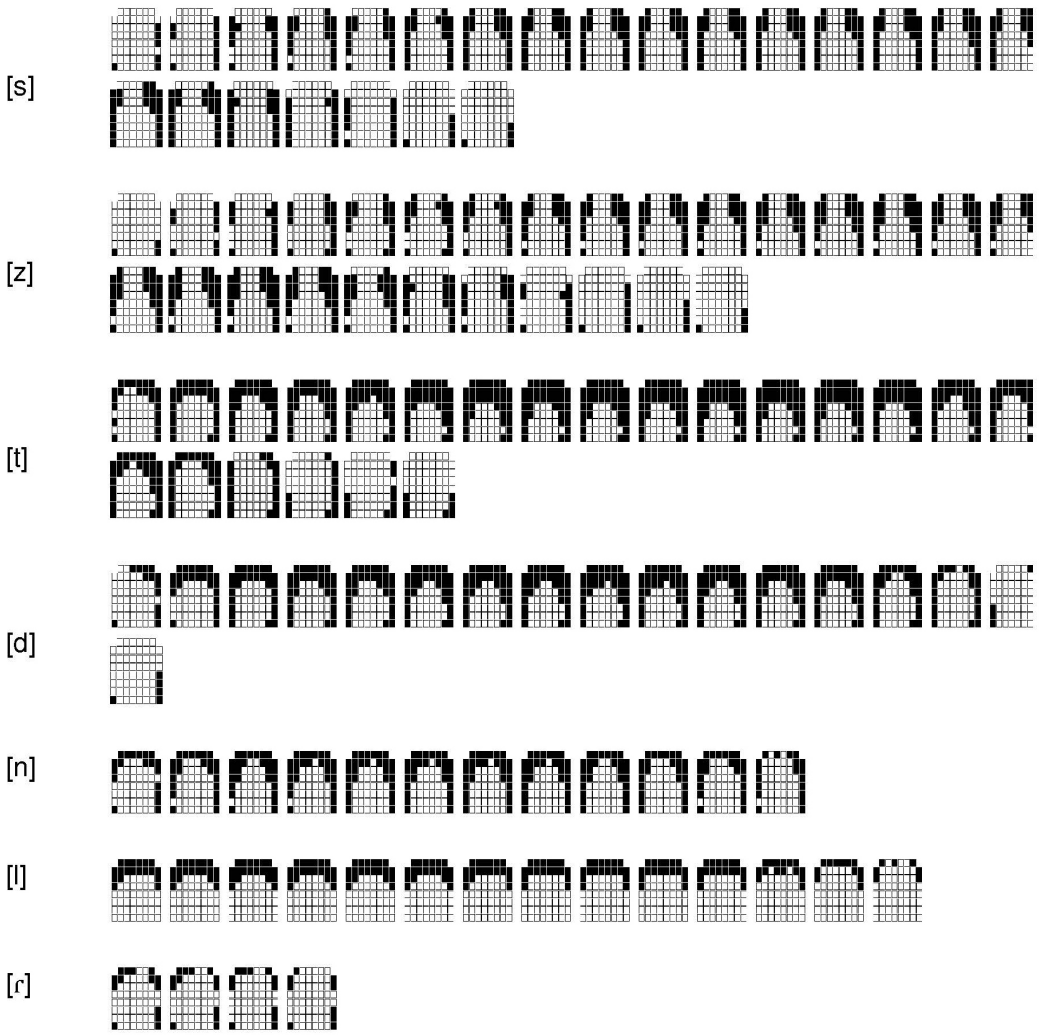

Figure 2. Sequency of palatograms showing tongue-palate contact for the studied alveolar phones from beginning to the end of the production

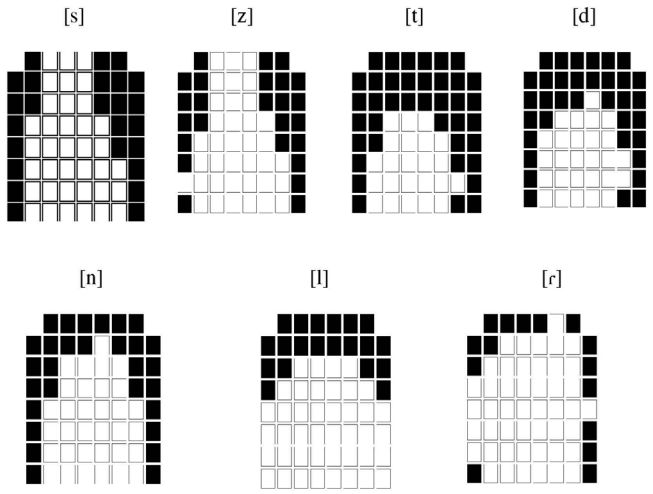

Figure 3. Alveolar phones palatograms in maximum constriction point

Phones [s] and [z]

To produce these phones, the tongue touched longitudinally the sides of the palate (columns one and eight), from the velar region to the alveolar region. This contact lasted until the end of the phone production, as it was observed by the indexes and the palatograms (Table 1 and Figure 2). The contacts with the alveolar region (LA1 and LA2), which characterized these phones, presented the following evolution throughout its production: gradual increase of contacts until the point of maximum constriction, followed by gradual decrease of contacts until the end of phone production. Contacts in the alveolar region were nonexistent since the beginning of these phones production. Therefore, the two or three central columns of the palatogram constituted a central channel. The point of maximum constriction – where the largest number of contacts in the alveolar region are observed, preserving the central channel mentioned above – remained stable for about half of its duration. Then the previous contacts gradually decreased, starting with the alveolar and post-alveolar regions, keeping the contact of the edges of the tongue with the palate. It was verified the tendency of longer contact with the right side of the palate for the investigated speaker, possibly due to his palate structure, which was slightly lower on this side. In the production of the phones [s] and [z], no contacts were observed in the central longitudinal axis of six columns in the palatal and velar regions and of three columns in the alveolar and post-alveolar regions. This was responsible for a central space that became narrowed, providing the conditions for air turbulence within the narrow channel formed.

In the point of maximum constriction, there was more tongue-palate contact in the alveolar and post-alveolar regions. The contact decreased in the posterior regions. Such constriction performance remained stable during the production of the phone (Figure 3).

The resemblance between the tongue-palate contact indexes of /s/ and /z/ was expected and confirmed in this study; there was no contact variation between voiced and voiceless phones (Table 1).

Phones [t] and [d]

It was observed that there was initially tongue contact with boundaries of the palate to produce these phones (columns one, seven and eight), from velar to alveolar region (LA1 to LV2), and these contacts remained until the end of the production (Table 1 and Figure 2). From the beginning, it could be noticed the contact of the tongue with the palate in the alveolar region, blocking the air follow, as shown by the alveolar index of the beginning, middle and end of the production. Therefore this phone is defined as "occlusive". There was gradual contact increase in the alveolar (LA1 and LA2) and post-alveolar (bigger in LPA1 than in LPA2) regions until a maximum constriction point was reached. At this point, there were contacts in the whole alveolar region, which extended to the post-alveolar region. The lateral contact of the tongue with the palate was sustained through the longitudinal axis in columns one, seven and eight, in all extension of the alveolar region, until the velar region. These contacts remained stable for approximately half of its duration. Then, the contacts gradually decreased from the central to the lateral region, keeping the tongue contact with the palate sides and alveolar region.

Among the alveolar phones, [t] and [d] demonstrated the higher percentage of tongue blade contact with the palate in alveolar and post-alveolar regions (Table 1 and Figure 3). All indexes of the phone [d] tended to be lower than those obtained for the [t] (Table 1). The duration of the phone [d] was also shorter when compared to the phone [t]. However, no statistical analysis was conducted to verify if these differences were significant due to the small number of data.

Table 1. Contact indexes from the beginning, middle and end of production, and contact percentage of maximum constriction point for each alveolar phone.

Indexes	/s/			/z/			/t/			/d/			/n/			/l/			/r/
	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	M
Alveolar	0.087	0.484	0.226	0.203	0.572	0.214	0.619	1.000	0.778	0.518	1.000	0.825	0.524	0.929	0.690	0.667	1.000	0.833	0.571
Post-alveolar	0.250	0.542	0.417	0.313	0.532	0.448	0.222	0.722	0.370	0.191	0.486	0.396	0.188	0.500	0.375	0.229	0.313	0.208	0.125
Palatal	0.167	0.313	0.287	0.146	0.313	0.303	0.125	0.382	0.230	0.078	0.250	0.229	0.125	0.250	0.250	0	0	0	0.063
Velar	0.188	0.243	0.222	0.209	0.250	0.188	0.229	0.313	0.278	0.186	0.250	0.250	0.188	0.250	0.208	0.063	0.063	0.063	0.200
CP (%)		39			40.9			57.52			48.4			46.8			33.9		17.7

Note: CP = contact point; B = beginning ; M = middle E = end

Phone [n]

During the production of this phone, it was noticed an initial contact of the tongue boundaries with the palate (columns one and eight) and the alveolar region (LA1). Then, there was constriction in the alveolar and post-alveolar regions, keeping the lateral contact in the longitudinal axis, with complete obstruction of air flow in oral cavity (Figure 3). For production of this phone, a rapid elevation movement of the tongue blade was noticed, forming the alveolar constriction. The tongue downgrade, to end the constriction, was slower, with greater duration (Table 1 and Figure 2).

Phone [l]

The analysis of the palatogram images for this phone calls attention due to the speed with which it is formed. From the beginning, it is noticed that the tongue blade touched the alveolar region of the palate (LA1 and LA2), with a small longitudinal extension for the post-alveolar region (only C1-2 and C7-8). According to similar indexes collected in the three moments of analysis, it remained there during the phone length (Table 1 e Figure 2). At the end of the phone production, it was noticed the reduction of the tongue contacts in alveolar region, the tongue body being completely downgraded. Due to its production characteristics, this phone was found to be typically apical alveolar, without placing the dorsum of the tongue in palatal and velar regions during its production (Figure 3). Regarding this, it differs from the occlusive alveolar phones [t] and [d], that presented tongue boundaries contact with the palate in the maximum constriction point. The [l] phone demonstrated a stable behavior, sustaining the maximum constriction point during almost all the phone length.

Phone [ɾ]

This phone presented few contacts, which were concentrated in the alveolar region, especially in LA1. However, the contacts were not present all over the extension of LA1 (Alveolar medium index of 0.57), and there were few contacts in LA2 and lateral columns (one, two and seven, eight), showing a restrict contact with the tongue summit (Table 1 and Figure 2). It was also noticed an interrupted contact column of the tongue with the palate in each side of the longitudinal axis (Figure 3). The tendency of the studied speaker in presenting higher contact to the right during the production of different phones could also be noticed during tap production [ɾ]. This phone has the characteristic of being produced in a fast way, with short duration. The shortest among the alveolar phones studied (Figure 2).

DISCUSSION

Since the studied sounds are classified as alveolar, it is expected that they have higher contact in lines one and two of the palatogram, that correspond to the alveolar region, and lower contact in post-alveolar, palatal and velar regions. That could be seen in the analyzed data. Palatal and velar contacts, when present, were performed by lateral tongue contact with the lateral boundaries of palate, demonstrating that the definition of phonological target is in the intersection of the central longitudinal axis and the transverse axis[6]. Fricative phones have lower indexes than occlusive phones, since they are characterized by the absence of tongue contact with the palate in the middle line, where the whirl air passes.

The analysis of palatogram sequences and quantitative EPG (indexes) data demonstrate variable tongue palate contact patterns, indicating variations in the lingual gesture performance for all the studied consonants. However, it was noticed that all of them have, in the maximum constriction point, most of their contacts in the alveolar region. These palatograms represent the articulatory target of the phone, the most stable point, and might be used as visual information of the articulatory production of alveolar phones both for studying and teaching language, including therapy use.

It was observed the following grading concerning the alveolar contact index in the point of maximum constriction: [t] and [d] > [l] > [n] > [s] e [z] > [ɾ] (Table1). The results demonstrate that alveolar phones could be divided into two groups according to the alveolar contact index: in one side, /t/, /d/, /l/ and /n/ as the ones that demonstrate higher alveolar contact index (indexes equal or near 1), in other words, present tongue palate contact in almost all electrodes in lines LA1 and LA2, showing complete tongue blade obstruction for the airflow. In the other side, the fricative phones [s] and [z], and the tap [ɾ], in which there are almost half of the contacts in LA1 and LA2 region (Alveolar index = 0.57). Non effective contact of fricative phones are expected and described in literature as necessary for the airflow passage between the tongue blade and the alveolus in the production of fricative sounds[7,8]. For the tap [ɾ], this can happen due to the speed and short extension of the contact. These results, in comparison to studies of other languages, show differences and similarities, as will be presented in the following.

In this study, it was demonstrated that during the production of [s] and [z] phones there were higher contacts with palate in alveolar and post-alveolar regions, with contact absence in longitudinal central axis, and longitudinal contact sustained in palate sides. Descriptions of [s] and [z] phones from different languages also demonstrate a central region without tongue palate contact, which constitutes an air channel that creates turbulence[9]; this is considered the main characteristic for fricative phones production[7]. In a research with English speaking adults[10] it was identified a central area with incomplete contacts in the anterior region of the palate that constitutes a central passage, filling from one to three electrodes of width, and a lateral contact throughout the palate, which they called "side arm". This description was widely used as a model for alveolar fricatives of English[5].

In this research it was not detected variation in tongue palate contact indexes between voiced and voiceless phones [s] and [z]. The same results were not achieved in comparison to other languages, for example, studies on English show that the width of the central passage for the /z/ phone was narrower than for the /s/[11].

A research shows the tendency of having variation in the tongue palate contact during the [s] production motivated by the co-articulation of adjoining vowels. In such study the results showed a higher contact for consonants followed by an /i/ than the ones followed by /a/ or /o/ or /u/[12]. Our study has not enabled such variation display since the analysis was focused on words with only one vowel [a] in every syllabus.

Comparing with other studies, the maximum constriction point of phones /s/ and /z/ produced in different situations and by different individuals, adults and children, may show a wide variation in tongue movement during the production of the phones; these variations are considered perceptively as normal[13]. Such variety was also noticed in a research on the production of these phones in English dialects variations[14]. In this study the electropalatography has been used to describe the phones /s/ and /z/ in the beginning and end of the syllabus. One result that called attention displayed that in 10% of /s/ and /z/ production there has been no central contactless. The authors' hypothesis is that this space without contact may has occurred between the electrodes, and it has not been detected in the EPG because the productions were considered as typical for a perceptive study. These data, however, contrast with research that describe the absence of central contact for the /s/ phone as a sign of speech disorder[15] and also with the hypothesis that naturally arises that such blocking in the alveolar region may result in a lateral friction or nasalization during the phone production. In the mentioned study of English, it was noticed the tendency of having a narrow central, of one or two columns width; therefore smaller than the one described in our study with Portuguese speaker.

More research about Portuguese language is necessary to discard the possibility that the lack of contact for this fricative phone does not indicate a speech disorder. The absence of central passage in alveolar fricatives has not been noticed in our data.

Among the factors that may cause greater variability of production of phones /s/ and /z/ and should be considered in future studies on Portuguese language, we focus the coda position (for example, a[s] patas and a[z] aves). In such position, the contact tongue palate is smaller and shorter, and the co articulator effect of the following phones is bigger than in syllabus attack position[16].

The [t] and [d] phones present the highest percentage of contact among the analyzed phones, due to the full transversal contact in anterior region. This broad contact of the tongue with the palate may be explained by the necessity of forming intraoral pressure for the production of these occlusive phones[5].

In this study the phone [n] demonstrate contact in alveolar region and in the sides of the palate. The same was observed for Catalan and Italian in a symmetric context of VCV, with the vowels /a/, /i/ and /u/[17]. The authors of the study, however, called attention for the great variability of contacts in the anterior region and their articulator sensibility before vowels; being noted variations for all the analyzed indexes of phone [n]. The authors ascribe this fact to the great flexibility that the tip of the tongue can present, adapting itself to the vowel context. In some languages there could be noticed the production of /n/ without total anterior occlusion, as may be observed in a study on nasal phones of Spanish[18] and Greek[19]. These results are different from the ones found in our study.

The contact with the edges of the tongue and the palate during the production of phone [n], systematically observed in this Portuguese study, was not described in a systematic way in studies on English and Australian; pointing out that in some productions of this phone there was no lateral constriction[5,20]. Thereby it is possible to notice the variability in the production of this phone in different languages, and one may conclude that such variations are more acceptable for the perceptive perspective[20]. The [n] phone has less contact than the occlusive [t] and [d], what may indicate that less articulatory force is necessary for its production in comparison with the occlusive.

In this study the phone [l] presented an apical alveolar contact without contact of the tongue dorsum with the palatal and velar regions. This articulatory production may be related with the following /a/ vowel, since results from a study on English demonstrated that the [l] phone is produced with an apical blocking and smaller dorsum palatal contact when adjacent to the vowel /a/; and with higher elevation of the dorsum and tongue blade contact when adjacent to the high vowel /i/[21].

It was observed that unlike other phones, that had tongue in the lateral longitudinal axis of palate, for the /l/ phone there could not be seen such contact in palatal and velar regions (indexes near 0). This is a necessary condition to permit air escaping by the edges of the tongue which dorsum is lowered, and justifies its classification as lateral. This articulator position was also noticed for /l/ phone in German when it was followed by the vowel /a/. However, with vowels /i/ and /u/ it was noticed an increase in post-alveolar contact, and a tendency of having contacts in the longitudinal axis in the palate sides[22]. Such data emphasizes the study of the co-articulation of consonant segment with different vowels for a better description of the language.

The tap phone [ɾ] is characterized by the concentrated contact in the tip of the tongue region. Such articulator characteristic was also observed in a study on Catalan[23] that compared the tap production and the vibrating R [r], possible variants of Brazilian dialect. The authors of the Catalan study founded that the tap presents higher apical alveolar contact and is shorter in relation to other phones of the language. It was noticed that in co-articulation with vowels in a CVC context, the consonantal segment displayed higher palatal contact when followed by the /i/ vowel than by the /a/. Therefore, there is more dorsum palatal contact with the vowel /i/. This conclusion points out to the possibility of having similar variations of tongue palate contact for the Portuguese language, depending upon the vowel context.

The tap [ɾ] was described as the smallest and shortest CP phone among the alveolar phones. Analyzed data in this study indicate possible weakness in this phone articulation as a result of the discontinuance on the contacts, similar to an approximant phone. The necessary articulator ability of the tip tongue in the production of /ɾ/ may eventually explain the latter acquisition of this phone in the phonetic development of the child, and the great number of speech disturbances related to this phone.

In our study, it was noted the stability in the production of alveolar phones in the three repetitions, although there was slight variation in the number of contacts, possibly influenced by the

speed of speech or the change in emphasis on the word. The results refer to the articulatory consistency that is observed in the speech of individuals without articulatory problems. However, it is important to consider that articulatory variations in the tongue palate contact among speakers of the same language[5,14], and among adults and children[22] should be highlighted when using comparative data among different groups. There are some reasons for variability in articulatory movements among speakers, including contextual influences of adjacent phonemes, vowel context, tone and speed of speech, among other[5].

It is important to consider some limitations of this study. Analyzed data were related to a CV context where the consonants are followed by vowel /a/. Future studies should exam those consonants in different vowel context to observe the co-articulatory effects; since there is a tendency during the production of dent alveolar consonants of elevation of the tongue dorsum, increasing the dorsum palate contact, due to the adjacent vowel respecting the progression /i/>/u/>/a/, as it was mentioned before for different phones. Another relevant aspect is that only the articulatory production of one speaker was taken into consideration, so that some of the data may reflect his oral peculiarities or dialectal characteristics; since other studies present the possibility of having variations in the number of contacts of each phone among different individuals[5,18], it is recommended some studies with a larger number of participants.

Finally, considering speech variation in different languages and dialects and variation in normal speech and speech affected by pathology it is concluded that descriptive studies of language phones are desirable to build up referential about speech production in languages and among different groups[15,24]. It is also noteworthy that typical speech articulator data, like the ones presented in this study, may contribute to provide normative data for speech-language pathology clinical practice in cases of speech disorders[5,7,13,15,25].

CONCLUSION

Considering the alveolar phones according to the articulatory perspective, we have concluded that fricative phones [s] and [z] are characterized by the absence of contact in the longitudinal central axis, in the alveoli level, and by the contact in the longitudinal lateral axis from the velar to the alveolar region. The plosive [t] and [d] display contact in all columns of alveolar region and in the longitudinal lateral axis, temporarily blocking the air flow and also present the highest number of contacts among the alveolar phones. The nasal phone [n] can be considered occlusive regarding the oral cavity level, since it presents total obstruction of the air flow in oral cavity both in alveolar and lateral region. The lateral phone [l] does not present the lateral longitudinal contact; contacts are concentrated in the alveolar region. The tap [ɾ] is characterized by its fast and few contacts production, most of them concentrated in alveolar region. Although all the analyzed phones are considered alveolar, it is noted that it is not only in this region that there is tongue palate contact. However, for all of them this region concentrates the highest constriction or proximity of articulators, what enables the inclusion of them in the alveolar group.

REFERENCES

1. Cagliari LC. A palatalização em português: uma investigação palatográfica [dissertação]. Campinas: Universidade Estadual de Campinas - Instituto de Estudos da Linguagem; 1974.
2. Reis C, Antunes LB. Estudo palatográfico de sons consonantais do português. In: Reis C. (Org.). Estudos em fonética e fonologia do português - Estudos linguísticos 5. Belo Horizonte: Fale-UFMG; 2002. p.225-44.
3. Hardcastle WJ. The use of electropalatography in phonetic research. Phonetica. 1972;25(4):197-215.
4. Marchal A, Reis C. Produção da fala. Belo Horizonte: Editora UFMG; 2012.
5. Gibbon F, Yuen I, Lee A, Adams I. Normal adult speakers' tongue palate contact patterns for alveolar oral and nasal stops. Int J Speech Language Pathol. 2007;9(1):82-9.
6. Reis C, Espesser R. Estudo eletropalatográfico de fones consonantais e vocálicos do português brasileiro. Estudos da Lingua(gem). 2006;3:181-204.
7. Gibbon F, Hardcastle W. Articulatory description and treatment of 'lateral /s/' using electropalatography: A case study. Br J Disord Commun.1987;22(3):203-17.
8. Reis C. Estudo eletropalatográfico das sequencias /s s/ e /s ʃ/ em português brasileiro. Rev Est Ling. 2007;15(2):29-57.
9. Shriberg LD, Kent RD. Clinical phonetics, 3rd edition. Boston: Allyn & Bacon; 2003.
10. Hardcastle W, Edwards S. EPG-based description of apraxic speech errors. In: Kent RD (Ed.). Intelligibility in speech disorders: Studies in speech pathology and clinical linguistics. Amsterdam- Philadelphia: John Benjamins;1992. p.287-329.
11. Dagenais PA, Lorendo LC, McCutcheon MJ. A study of voicing context effects upon consonant linguapalatal contact patterns. J Phonetics.1994;22:225-38.
12. Stone M, Faber A, Raphael LJ, Shawker TH. Cross-sectional tongue shape and linguopalatal contact patterns in [s], [sh], and [l]. J Phonetics. 1992;20:253-70.
13. Roberts A, McLeod S, Sita J. Using the EPG to describe normal and impaired /s/ and /z/. Adq Knowl Speech, Lang Hear. 2002;4(3):158-63.
14. McLeod S, Roberts A, Sita J. Tongue/palate contact for the production of /s/ and /z/. Clin Linguist Phon. 2006;20(1):51-66.
15. Gibbon FE. Abnormal patterns of tongue-palate contact in the speech of individuals with cleft palate. Clin Linguist Phon. 2004;18(4-5):285-311.
16. Byrd D. Influences on articulatory timing in consonant sequences. J Phonetics. 1996;24:209-44.
17. Recasens D, Farnetani E, Fontdevila J, Pallarès MD. An electropalatographic study of alveolar and palatal consonants in catalan and Italian. Lang Speech. 1993;36(2,3):213-34.
18. Planas AM. Características linguopalatales de la nasal palatalizada en español. EFE. 2009; XVIII:161-74.
19. Nicolaidis K. An electropalatographic study of Greek spontaneous speech. J Int Phonetic Assoc. 2001;31:67-85.
20. McLeod S. Australian adults' production of /n/: an EPG investigation. Clin Linguist Phon. 2006;20(2-3):99-107.
21. Farnetani E. Coarticulation and reduction in coronal consonants: comparing isolated words and continuous speech. Quaderni del Centro di studio per le Ricerche di Fonetica de C.N.R. 1991;X:103-10.
22. Recasens D, Fontdevila J, Pallarès MD. Linguopalatal coarticulation and alveolarpalatal correlations for velarized and nonvelarized /l/. J Phonetics. 1996;24:165-85.
23. Recasens D, Pallarès MD. A study of /R/ and /r/ in the light of the DAC: coarticulation model. J Phonetics. 1999;27:143-69.
24. Tabain M. An EPG study of the alveolar vs. retroflex apical contrastin Central Arrernte. J Phonetics. 2009;37:486–501.
25. Nordberq A, Lohmander A, Carlsson G. Electropalatography in the description and treatment of speech disorders in five children with cerebral palsy. Clin Linguist Phon. 2011;25(10):831-52.