HISPANIC STUDIES
review

Place of articulation asymmetry in the lenition of voiced stops in Buenos Aires Spanish

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Abstract

In Spanish, the voiced stops /b d g/ alternate with a lenited approximant allophone [β̞ ð̞ ɣ̞], which can vary in degree of weakening. This study reports on new production data from Buenos Aires Spanish to explore the effect of place of articulation on the extent to which stops in lenition contexts will weaken. The data are analyzed by applying the categorization scheme for three subtypes of spirant approximant proposed by Martínez-Celdrán (2004, 2013). The results show that the labial is realized as the least weakened variant statistically significantly more often than the dentals and velars. This asymmetry is accounted for by appealing to the Aerodynamic Voicing Constraint (Ohala & Riordan, 1979) and the specific articulatory characteristics of producing stops at different places of articulation, an account that finds support in synchronic, diachronic, and typological patterns.

1. Introduction

One of the most frequently discussed phonological processes of Spanish is the alternation between the voiced stops /b d g/ and their approximant allophones [β̞ ð̞ ɣ̞], known as spirantization or lenition of voiced stops or the stop/spirant alternation. According to the traditional description of this alternation, the voiced stops are realized as the full stop allophones in utterance-initial position and after homorganic consonants (nasals and /l/ in the case of /d/), while the approximants appear in all other contexts (Harris, 1969; Lozano, 1978; Mascaró, 1984, 1991; Navarro Tomás, 1918). This alternation, expressed in rule form, is given below[1] in Figure 1.

/b d g/ → [β̞ ð̞ ɣ̞] / after vowels, glides, rhotics, fricatives, laterals (except for /d/)
→ [b d g] / after pause (utterance-initially), after nasals, after laterals (only /d/)

Figure 1. The traditional rule-based expression of the stop/spirant alternation

The alternation between the stop and continuant variants is often conceived of as an instance of consonantal weakening or lenition, where the stronger stop allophone is found in strong positions (utterance-initially and after nasal consonants) and the weaker approximant[2]

1 Although the direction of the change is frequently assumed to be an underlying voiced stop becoming an approximant in certain contexts (Goldsmith, 1981; Harris, 1969; Mascaró, 1984), others have also characterized the change as being the reverse: an underlying approximant becoming a stop (Baković, 1995; Barlow, 2003; Lozano, 1978). For the purposes of this paper, I will assume that the underlying segment is the stop.

2 Earlier research proposed that this alternation was between the voiced stops [b d g] and a fricative realization [β ð ɣ], but, acoustic studies have determined that in fact the "fricatives" are better described as approximants due to their low level of turbulence and vowel-like formant structure (Martínez-Celdrán, 1984; Romero, 1995).

allophone is found in weaker positions (after continuant segments) (Carrasco, Hualde & Simonet, 2012; Cole, Hualde & Iskarous, 1999; Kingston, 2008).

Experimental studies have found variation within the lenited variant, where the approximant weakens to different degrees depending on factors such as stress placement, position of the consonant within a word, and preceding and following segmental context (Carrasco et al., 2012; Colantoni & Marinescu, 2010; Cole et al., 1999; Eddington, 2011; Ortega-Llebaria, 2004; Simonet, Hualde & Nadeu, 2012). These studies have typically taken one of two approaches to capturing the variability of the stop/spirant alternation. The first relies on acoustic measures, such as duration and intensity relative to a neighbouring vowel, which gives a fine-grained illustration of the variability of the sounds involved (e.g. Cole et al., 1999; Eddington, 2011; Ortega-Llebaria, 2004). The second approach uses a categorization scheme that assigns individual productions of /b d g/ into specific categories that reflect the extent of lenition. For example, Colantoni and Marinescu (2010) categorize instances of Argentine Spanish /b d g/ into stops, approximants, and full deletions, and Dalcher (2008) categorizes the stops of Florentine Italian into weak approximants, approximants, fricatives, semifricatives, fricated stops, and stops. Similarly, Martínez-Celdrán's (2004, 2013) categorization scheme for the lenition of Spanish voiced stops provides subcategories of approximant, allowing us to describe variation within the lenited allophone. As explained by Martínez-Celdrán, the term 'approximant' as it currently exists in the Handbook of the International Phonetic Association (IPA 1999) encompasses a variety of sounds, some of which have significant acoustic or articulatory differences from each other. He proposes that the category 'approximant' should be a super-category that has several subcategories. One of the subcategories would be called 'spirant approximants' and would be made up of [β̞ ð̞ ɟ̞ ɣ̞]. Excluding the palatal [ɟ̞], the remaining spirant approximants correspond to the lenited variants of /b d g/ that we find in the stop/spirant alternation in Spanish. Martínez-Celdrán (2004) also notes that there is variation in the degree of openness of the spirant approximants, giving rise to three subcategories within that category: closed spirant approximants (the least open), open spirant approximants, and vocalic spirant approximants (the most open).

In addition to the factors mentioned above, some previous experimental studies have suggested that place of articulation might have an effect on the degree of weakening of the Spanish voiced stops. However, many studies have only included a subset of the three places (e.g. only /g/ in Cole et al., 2009; only /b g/ in Ortega-Llebaria, 2004; only /d/ in Simonet et al., 2012) or have focused more on various other factors, making interpretation of the place findings more difficult (Carrasco et al., 2012; Colantoni & Marinescu, 2010; Eddington, 2011). The purpose of the current study is to apply the classification scheme provided by Martínez-Celdrán (2004, 2013) to determine if there is any effect of the place of articulation on the extent to which the /b d g/ will weaken in Buenos Aires Spanish. Although the phenomenon of lenition of the voiced stops is commonly discussed in the literature, less is known about interdialectal variation in the pattern, as noted in Carrasco et al. (2012). This study contributes to the body of knowledge about how the dialects of Spanish vary in their weakening of the voiced stops by providing a close look at the pattern of lenition in Buenos Aires Spanish, which, to my knowledge, has not been specifically examined before[3].

The remainder of the paper is organized as follows. §2 gives the methodology for the experiment, detailing the participants who took part, the stimuli, the procedure and how the data

3 Colantoni & Marinescu (2010) included speakers from two provinces of Argentina: Corrientes (which Lipski (2014: 3) includes in a different dialect classification from Buenos Aires) and San Juan, which is approximately 1100km to the west of Buenos Aires.

were analyzed. §3 provides the results, §4 gives a discussion of the findings, and §5 summarizes the conclusions.

2. Method

The data considered in this paper are taken from a larger study that was designed to explore the effect of surrounding segmental context on the realization of /b d g/. Below the experimental procedure is discussed in its entirety to clarify which data specifically are included in this study and motivate the choices.

2.1 Participants

Six participants (4 females and 2 males), all born and raised in the city of Buenos Aires, Argentina, took part in the experiment. Table 1 below provides details about the participants including sex, age at which they arrived in Canada and at the time of the study, and the number of years they had lived in Canada at the time of the study. All were between the ages of 30 and 57 and had either completed or were in the process of completing a university education. The participants were recruited through the University of Toronto and were compensated $10 for their time. Each participant had been in Canada for a different length of time, ranging from 3 to 17 years, with four of the six participants having been in Canada for between 3 and 5 years. All of the participants spoke English as a second language and with a noticeable accent. Although their English proficiency levels were not specifically assessed, each participant was able to converse easily with the author in English and had no difficulty performing the translation portion of the production task (discussed in the next section).

Speaker #	Age	Sex	Age of arrival in Canada	Years in Canada
1	57	F	40	17
2	38	M	33	5
3	39	F	36	3
4	42	F	31	11
5	30	F	26	4
6	43	M	38	5

Table 1. Participant details

2.2 Procedure & Materials

In the experiment, the participants were shown English words on a PowerPoint slide and their task was to translate the words into Spanish and then produce them in seven different sentences, which were also provided on the slide. The Spanish translation of the English word always had one of /b/, /d/ or /g/ as its initial sound. An example slide is given in Figure 2 for the /b/-initial Spanish word *boca* /boka/ 'mouth'. On the slide, the English word ('mouth') was presented followed by an equals sign and a line indicating that the participant should translate the English word to Spanish. A small image was present to help make the intended Spanish word more obvious. With the Spanish word in mind, the participant then produced the token in the

seven different sentences provided on the slide, one after another[4]. After completing the set of sentences, the participant read aloud the list of sentences a second time, generating the complete set twice for each token. The participants completed a practice session first using ten words not included in the test session in order to become familiar with the task and the sentences.

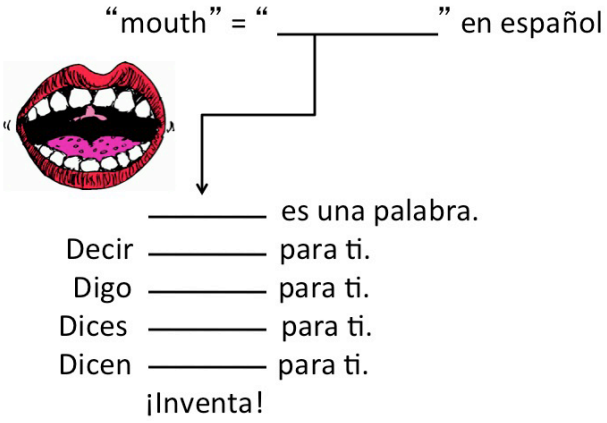

Figure 2. Sample slide from production task

The sentences and their English glosses are given in Figure 3. Some of the sentences situate the voiced stop in contexts where lenition is not expected (such as in isolation, utterance initially or after a nasal). Others put the stops in contexts where lenition is expected (such as after /ɾ/, after vowels, or after /s/).

a.	in isolation	
b.	_____ *es una palabra.*	'_____ is a word'
c.	*Decir* _____ *para ti.*	'To say _____ for you'
d.	*Digo* _____ *para ti.*	'I say _____ for you'
e.	*Dices* _____ *para ti.*	'You say _____ for you'
f.	*Dicen* _____ *para ti.*	'They say _____ for you'
g.	A sentence generated spontaneously by the participant.	

Figure 3. List of contexts in the production task

As noted above, the data presented in this paper were taken from a larger study in which the effect of the preceding context was one of the factors investigated. Although, in addition to intervocalic position, lenition is also expected after rhotics (as in sentence (c)) and fricatives (as in sentence (e)), previous work has found that the voiced stops may be less weakened in these contexts as compared to intervocalic (Carrasco et al., 2012). Since the purpose of the current study

4 Since the production task required translation from English, in some cases the participants would produce a different Spanish word from the one intended. For example, when presented with the English word 'lady' (and shown a cartoon image of a woman), the participants sometimes provided the Spanish word *mujer* instead of the desired *dama*, both of which refer to women. Before the experiment began, I explained to the participants that in each case there was a particular word I was looking for and that if they provided a different one I would ask them to try again. So when a participant said *mujer* I asked him or her to think of another word meaning 'lady' and once the desired word was elicited we continued with the experiment.

is to explore the variability within the weakened variants, the data are limited to intervocalic context, which is prototypical for spirantization (Colantoni & Marinescu, 2010, Simonet et al., 2012). While the context in sentence (d) has been labeled 'intervocalic', it is restricted to only post /o/ and does not include other preceding vowels, following a similar approach in Carrasco et al., (2012)[5].

The stimuli consisted of 30 genuine Spanish tokens beginning with /b/, /d/ or /g/ and were controlled for following vocalic context including the vowels /a e i o u/[6]. For each place of articulation there were 10 tokens with two per following vowel. All of the stimuli are provided in the appendix. Most were of the form CV.CV, but some were CVC. CV (such as *barco* /baɾ.ko/ 'ship'). In all of the tokens, the target voiced stop was the onset of a word-initial stressed syllable. Previous experimental studies have found that voiced stops that are the onset of a stressed syllable may weaken less extensively than those that are the onset of an unstressed syllable (Colantoni & Marinescu, 2010; Cole et al., 1999; Ortega-Llebaria, 2004), so since all of the stimuli in this study are the onsets of stressed syllables, we might expect to see less lenition overall than was observed in other studies. Although the voiced stops in the current study are produced in lenition contexts that span a word boundary, they are still expected to lenite since previous work has found that weakening occurs across word boundaries as well as within words (Carrasco et al., 2012; Cole et al., 1999; Fernandez, 1982).

A translation task was used in order to avoid any effect of having the orthographic form of the Spanish words visible on the slides. If the graphemes for /b d g/ were presented, it is possible that the participants would be less likely to produce weakening in an attempt to stay faithful to the spelling of the word.

The experiment was performed in the sound-attenuated booth at the University of Toronto phonetics lab using a Sound Devices 722 digital recorder and DPA 4011-TL shotgun microphone with a sampling frequency of 44,100 kHz and 24-bit resolution on a mono channel.

2.3 Data analysis

2.3.1 The categorization scheme

Each underlying voiced stop was labeled for its particular surface variant by applying the categorization scheme proposed by Martínez-Celdrán (2004, 2013). This categorization scheme is based entirely on a set of well-defined visual characteristics of the segments in the spectrogram. Using these characteristics we can categorize individual productions of /b d g/ into one of five surface realizations: stop, fricative, closed spirant approximant, open spirant approximant, or vocalic spirant approximant. This section explains the set of characteristics that Martínez-Celdrán proposes to perform the categorization and provides examples from the current data of each of these possible categories.

The least lenited of the five possible categories is the stop. According to Martínez-Celdrán's approach, a surface stop will have a visible release burst, which is the characteristic that distinguishes stops from other weaker realizations. Figure 4 shows a stop realization of the /d/ in *dice*

5 Note that in Carrasco et al. (2012) the only preceding vowel context was /a/, but the motivation for only including one preceding vowel quality is the same as in the current study.

6 All 5 Spanish vowels are included here in order to generate a natural and varied set of stimuli that is balanced for following vowel quality, but determining the effect, if any, of following vowel quality on degree of weakening is not one of the goals of this study.

/dise/ 'he/she says' in intervocalic position[7],[8]. The release burst is marked with a black vertical arrow. We also see a visible voice bar before the release burst since the underlying voiced stops are realized as prevoiced or fully voiced in Spanish (Abramson & Lisker, 1973; Navarro Tomás, 1918: 79), but no glottal pulses above the voice bar.

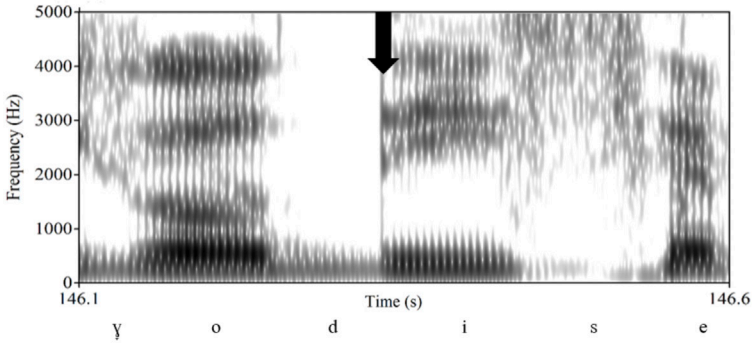

Figure 4. Spectrogram of an intervocalic stop

The least lenited continuant variant of the underlying stop is the fricative. Following Martínez-Celdrán's categorization scheme, a fricative will show aperiodic noise and lack of formant structure. Both of these characteristics distinguish fricatives from stops, which lack aperiodic noise and have a release burst, and from approximants, which lack aperiodic noise, but have formant structure, as we will see below.

Figure 5 shows an example of a fricative realization of the /b/ in *boca* /boka/ 'mouth'. The rough boundaries of the fricative are marked with black arrows. In between the arrows we can see the aperiodic noise, but no well-defined formant structure like that found in the surrounding vowels.

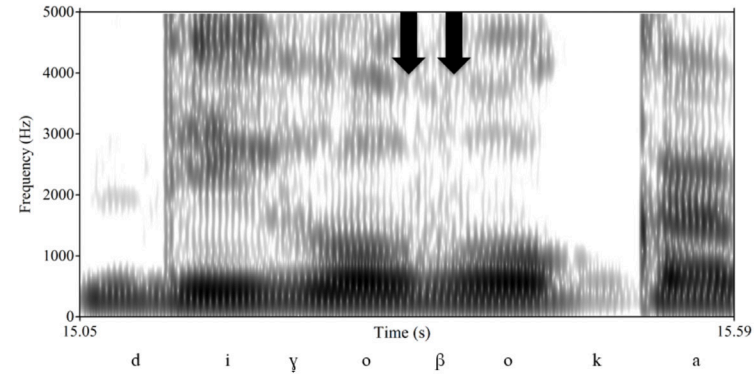

Figure 5. Spectrogram of an intervocalic fricative

The next several figures show examples of approximants, corresponding to the three subtypes of spirant approximants proposed by Martínez-Celdrán (2004): closed, open, and vocalic spirant

7 Recall that all of the target words were realized in the carrier phrase *Digo* _____ *para ti.* The spectrograms in this section show various parts of the carrier phrase in addition to the target segment.

8 As will be discussed in §3, a stop realization in intervocalic position was rare, since this is one of the most likely contexts for lenition.

approximants. The closed spirant approximant is the least weakened of the three subtypes. As explained by Martínez-Celdrán and Regueira (2008), the closed spirant approximant looks like a stop without a release burst. Like a stop, it lacks glottal pulses above the voice bar. Figure 6 shows an example of the closed spirant approximant in the /b/ in *buzo* /buso/ 'scuba diver'. The rough boundaries of the /b/ are marked with vertical arrows.

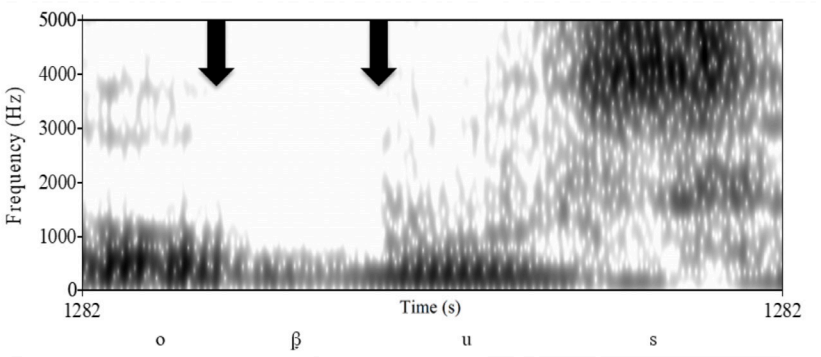

Figure 6. Spectrogram of an intervocalic closed spirant approximant

The next type of spirant approximant is the open variant. According to Martínez-Celdrán (2013), open spirant approximants show fairly well-defined formant structure in the transition from the preceding vowel and moving into the following vowel and have weak glottal pulses above the voice bar, with no aperiodic noise. The presence of glottal pulses distinguishes the open variety from the closed spirant approximant.

Figure 7 shows a /b/ in *boca* /boka/ 'mouth', which is categorized as an open spirant approximant using Martínez-Celdrán's categorization scheme. Between the black arrows we see glottal pulses that are noticeably weaker than those of the surrounding vowels, particularly in the middle of the approximant, with more well-defined formant structure at the onset and offset, but no aperiodic noise, which would signal a fricative.

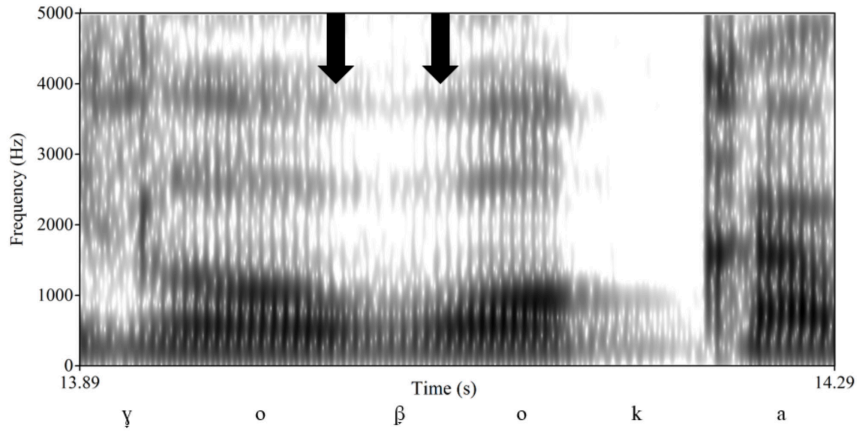

Figure 7. Spectrogram of an intervocalic open spirant approximant with low relative intensity

Martínez-Celdrán and Regueira (2008) note that open approximants can vary in how intense

they are relative to the surrounding vowels, reflecting varying degrees of openness of the approximants. The approximant in Figure 7 has relatively low intensity compared to the surroundings vowels.

Figure 8 below shows an open approximant realization of the /d/ in *dijo* /dixo/ 'he/she said' where the intensity of the [ð̞] is higher than the intensity of the [β̞] in Figure 7 above. Here, the intensity of the approximant is closer to that of the surrounding vowels, but the underlying /d/ is still classified as an open approximant because it meets the criteria for an open spirant approximant specified above.

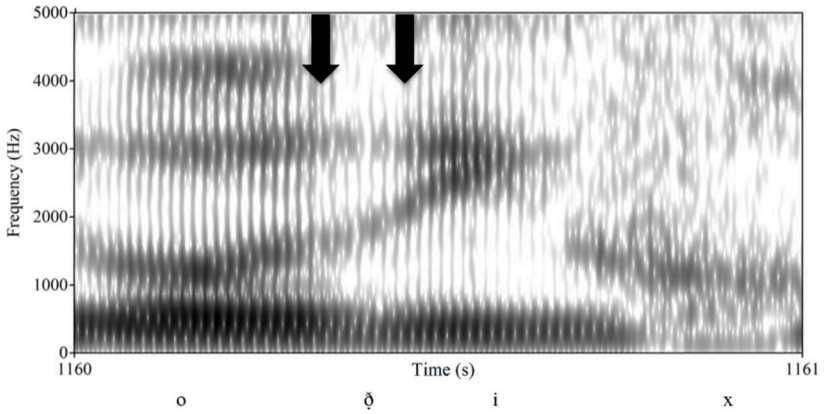

Figure 8. Spectrogram of an intervocalic open spirant approximant with high relative intensity

The most lenited variant is the vocalic spirant approximant. Martínez-Celdrán's categorization scheme specifies that vocalic approximants are audible in a recording, but look essentially like the surrounding vowels. That is, we see no weakening in the glottal pulses and no visible change in how well defined the formant structure is at any point in the approximant as compared to the surrounding vowels. According to Martínez-Celdrán, a slight dip in intensity gives some indication of where the boundaries of this segment might be. Figure 9 provides an example of a vocalic approximant in the realization of the /g/ in *gota* /gota/ 'droplet'. The black arrow notes the position of the slight dip in intensity (represented by the thin black line), but determining precise onset and offset positions of the approximant cannot be done accurately due to the extreme visual similarity of the vocalic spirant approximant to the surrounding vowels. All we can say for certain is that the dip in intensity occurs within the duration of the approximant.

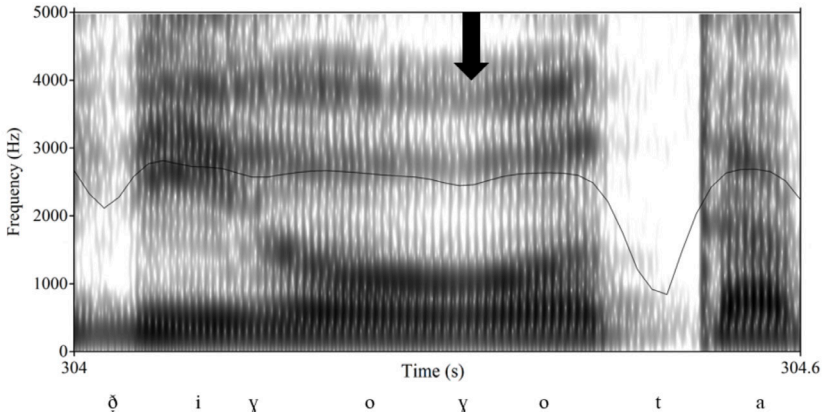

Figure 9. Spectrogram of an intervocalic vocalic spirant approximant

2.3.2 Categorization procedure

The data in this study were observed via the spectrograms and waveforms generated in Praat (Boersma & Weenink, 2017). The process of categorization had three stages. In the first stage, the author evaluated each segment according to Martínez-Celdrán's categorization scheme described above and assigned one of the five surface realization labels. The second stage constituted a second pass of the data, applying the categorization scheme again[9], while the column in the data file containing the categorization from the first stage was not visible. This was done to make the second pass of categorization as independent as possible from the first. Reliability between the first and second stages was high, with 90% of the segments being categorized in the same way in both stages. A total of 32 segments did not match between the first and second stages. In the third stage, these 32 discrepancies were examined one at a time in order to make a final decision about the best categorization. Of these 32, 28 involved differences of only one "position" on the scale of possible realizations; that is, 28 were differences between closed and open or between open and vocalic. Only four involved differences of more than one position, such as between closed and vocalic. After each discrepant segment was considered, only 20 were changed from the Stage 1 categorization.

Since there were six participants, each of whom produced the 30 /b d g/-initial tokens in intervocalic position two times, the total number of stimuli produced was 360. Nine tokens were discarded due to a problem in the recording such as the participant coughing, laughing, accidentally knocking the microphone or leaving a pause after the word *Digo* causing the target stop not to be in intervocalic position. Twenty-six of the target sounds (7%) were realized as stops and nine (3%) were realized as fricatives. Both of these realizations are infrequent because they are disfavoured in intervocalic position (Colantoni & Marinescu, 2010; Simonet et al., 2012). Since the goal of this study is to explore the nature of the approximant variant, the small number of stops and fricatives will be left out of subsequent analyses. So the following discussion includes 316 tokens (103 /b/, 100 /d/, and 113 /g/), all realized as spirant approximants (closed, open or vocalic).

3. Results

Table 2 below shows the percentage of underlying stops that were realized as each subtype of spirant approximant. The raw counts are provided in brackets next to the percentage.

	% (N)
closed	21% (66)
open	47% (148)
vocalic	32% (102)

Table 2. Percentage and N of closed, open, and vocalic spirant approximants

The open variant is most frequent, making up 47% of all the tokens. The other two subtypes

9 Note that there were many months in between the first and second passes, so it is unlikely that the author had any memory of how individual sounds were categorized in the first pass.

are not infrequent, however, with vocalic approximants making up 32% and closed 21% of the tokens. Table 3 shows the proportion of each spirant approximant by place of articulation. The shaded cells represent those with the highest proportion of segments.

	/b/	/d/	/g/
closed	42% (43)	9% (9)	12% (14)
open	42% (43)	56% (56)	44% (49)
vocalic	16% (17)	35% (35)	44% (50)

Table 3. Percentage and number of closed, open, and vocalic spirant approximants by place

Table 3 suggests that in the labials, the distribution is centred on the closed (least weakened) and open variants, while in the velars, the distribution is centred on the open and vocalic (most weakened) variants. The dentals fall in the middle with the distribution centred on the open variant, but with a significant proportion (35% - shown in the lighter shading) being realized as vocalic as well. So while /b/ seems to skew towards the less weakened end of the spectrum of spirant approximants, /g/ and /d/ do the opposite, skewing towards the more weakened end of the spectrum. This asymmetry is particularly visible in terms of the two extrema: /b/ is realized as the closed variant approximately four times more often than /d/ and /g/, and as the vocalic variant less than half as often as /d/ and /g/.

Using a Fisher's exact test, place of articulation was found to be statistically significantly related to the distribution of the three spirant approximant types (Fisher's exact test, $p < 0.0001$)[10]. This result reveals that there is some relationship between place of articulation and approximant type, but it does not indicate which of the cells in Table 3 are significantly different from each other. To determine this, follow-up pairwise comparisons were performed using the fisher.multcomp() function in the *RVAideMemoire* package (Hervé, 2019). The *p*-values were corrected for multiple comparisons using the Benjamini and Hochberg method (Benjamini & Hochberg, 1995) and are shown in Table 4 below.

As we can see from Table 4, several of the pairwise differences are statistically significant. First, we compare /b/ and /d/. The differences between the proportions of closed and open and between the proportions of closed and vocalic approximants are both significant (Fisher's exact test, $p < 0.0001$ for both comparisons), but the difference in the proportions of open and vocalic approximants is not (Fisher's exact test, $p = 0.2862$). We find a similar result comparing /b/ and /g/, except that the comparison between the proportions of open and vocalic approximants is also significant (closed vs. open: $p = 0.0014$; closed vs. vocalic: $p < 0.0001$; open vs. vocalic: $p = 0.0142$). These comparisons yield two main findings: 1. /b/ is realized as closed more often than /d/ and /g/, and 2. /g/ is realized as vocalic more often than /b/.

None of the pairwise comparisons between /d/ and /g/ were significant, indicating that the dental and velar stops pattern in the same way in terms of their likelihood of being realized as one of the three spirant approximants.

10 This test determines the extent to which two categorical variables are related and was used because of its robustness to small sample sizes as compared to a chi-square test. It was implemented using fisher.test() in the *stats* package (R Development Core Team, 2013).

	/b/ vs. /d/	/b/ vs. /g/	/d/ vs. /g/
closed vs. open	0.0000	0.0014	0.2862
closed vs. vocalic	0.0000	0.0000	1.0000
open vs. vocalic	0.2862	0.0142	0.1638

Table 4. p-values for pairwise comparisons by spirant approximant type and place of articulation

The finding that /b/ is produced as the closed variant more than the other places is maintained to a considerable extent at the individual-speaker level as well. Figure 10 shows the proportions of each stop /b d g/ that are realized as the three types of spirant approximant for each of the six participants. The exact percentages are provided in the appendix. The black bars in Figure 10 represent the proportion of each place of articulation that is realized as the closed approximant. We can see that within each speaker except Speaker 5, the black bar for /b/ is higher than the black bars for /g/ and /d/. So five of the six participants reflect the group-level pattern where /b/ is realized as the least weakened variant more often than the other two places of articulation[11].

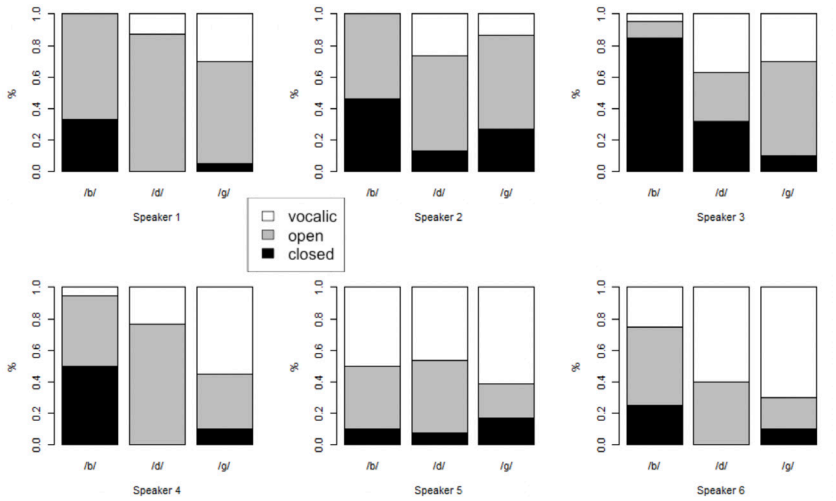

Figure 10. Proportion of closed, open, and vocalic approximants by place of articulation by speaker

4. Discussion

This study explored the distribution of three subtypes of spirant approximant (closed, open, and vocalic) in the lenition of the voiced stops in Buenos Aires Spanish. The results found that there was an asymmetry in the extent to which the three places of articulation weakened, as re-

11 A reviewer notes that Speaker 3 produced /b/ as a closed approximant 85% of the time and asks to what extent this speaker carried the group-level pattern for /b/. If we remove Speaker 3 from the data and look at the overall pattern, as we did in Table 3, we find that /b/ is realized as closed 31% of the time, as open 50% of the time, and as vocalic 19% of the time. The proportions for /d/ and /g/ are only marginally changed with the removal of Speaker 3. This suggests that Speaker 3's high proportion of closed approximant /b/ does impact the overall pattern. However, a Fisher's exact test with Speaker 3 removed still found a significant relationship between place and approximant type (Fisher's exact test, $p < 0.0001$) and follow-up pairwise comparisons confirmed that /b/ is still produced as closed more often than /g/ (Fisher's exact test, $p < 0.0001$) and /d/ (Fisher's exact test, $p < 0.0001$) as compared to vocalic.

flected in the proportion of each stop realized as the three spirant approximant types. The labial was found to weaken the least, being realized significantly more often as closed than the dental and velar, which did not differ from each other in the extent to which they weakened. Furthermore, the velar was found to weaken the most in that it was realized as the vocalic approximant significantly more often than the labial.

Asymmetries in the patterning of voiced stops between labials and more back places of articulation have been widely reported. Synchronic patterns from other languages show many examples where either /g/ weakens to a greater extent than /b/ (for example, via spirantization) or where voicing is abandoned altogether via devoicing more often in /g/ than in /b/. Catalan provides an example from a related language. The voiced stops in Catalan undergo a similar spirantization process to that of Spanish. In their study of Majorcan Catalan, Hualde, Nadeu and Simonet (2010) found an asymmetry in the lenition of the voiced stops where /b/ was more constricted than /d/ and /g/. In Dalcher's (2008) study of lenition of Florentine Italian stops, /b/ was weakened the least in terms of several acoustic measures, /g/ was weakened the most, and /d/ fell in the middle. Lousada, Jesus and Hall (2010) explored the voicing contrast in European Portuguese stops and found that the farther back the place of articulation of voiced stops, the more common devoicing.

We can find examples from non-Romance languages as well. Podesva, Eckert, Fine, Hilton and Jeong (2015) found in their study of stop voicing in Inland California English that the strength of voicing (as measured by intensity of the closure relative to the following vowel) was reduced as the place of articulation moved from front to back. As discussed in Napoli, Sanders and Wright (2014), in Tonkawa (an extinct language isolate), word-final /g/ devoices, but not /b/ or /d/ (Hoijer, 1933), and in Jamsay (a Dogon language spoken in Mali), intervocalic /g/ spirantizes, but not /b/ or /d/ (Heath, 2008).

Labial voiced stops also show evidence of resisting both weakening and devoicing to a greater extent than velars in diachronic patterns. An example of this comes from the history of Spanish voiced stops. Latin included a three-way contrast between voiceless geminates, voiceless singletons, and voiced stops at each of the labial, dental, and velar places of articulation. During the development from Latin to Old Spanish, this contrast shifted with all the stops leniting. The voiceless geminates became singleton voiceless stops (e.g. CUPPA > *copa* 'wine glass') and the voiceless singletons became voiced (CŪPA > *cuba* 'cask'). The voiced stops also lenited, but the extent of the change depended on the place of articulation (Penny, 2002: 76). Whereas the labial voiced stop became a fricative (CIBU > *cevo* 'food' and then later *cebo* 'bait'), the dental and velar voiced stops were deleted altogether (CRUDĒLIS > *cruel* 'cruel' and REGĀLIS > *real* 'royal'). Penny (2002: 77-81) notes that there was a small number of cases in which the Latin /d/ and /g/ were not deleted and were instead produced in Old Spanish as fricatives, but this contrasts with /b/ where the fricative realization was the most common.

French underwent a similar lenition in its development from Latin (Pope, 1934: 138). Whereas the Latin /b/ was lenited to the labiodental fricative /v/ in Modern French (HABĒRE > *avoir* 'to have'; Pope, 1934: 258), Latin /d/ and /g/ were lenited to Ø (RŪGA > *rue* 'street'; Pope, 1952: 261, NŪDUM > *nu* 'naked'; Pope, 1952: 270). In Tuscan Italian, the velar stops were the first to undergo lenition and remained the only place to lenite for approximately 250 years (Dalcher, 2008; Izzo, 1972).

These asymmetries between labials on the one hand and other places of articulation on the other hand are often accounted for by appealing to the aerodynamics of producing voicing in stops. To produce voicing, the vocal folds must be in the necessary configuration in terms of

tension and adduction and there must be sufficient airflow through the vocal folds (Ohala, 1983, 1997). For voicing to be maintained, subglottal air pressure must be higher than oral air pressure (supraglottal air pressure) by a certain amount. If supraglottal air pressure becomes too high relative to subglottal air pressure, voicing ceases. This is known as the Aerodynamic Voicing Constraint (AVC: Ohala & Riordan, 1979; Ohala, 1983, 1997). As such, maintaining voicing during a stop presents a challenge: air flows into the oral cavity, but it does not flow out. As a result, when producing a stop, supraglottal air pressure increases rapidly and voicing is cut off quickly. One way that languages can stave off this cessation of voicing is by increasing the size of the oral cavity, either passively or actively (Ohala, 1983, 1997). In active expansion, an active articulator is moved, such as lowering the larynx or tongue. Passive expansion results because the surfaces of the oral cavity have some compliance, meaning they are somewhat flexible, and can expand, increasing the size of the oral cavity.

If we compare the physiological nature of producing voiced stops at different places of articulation (as others have done: e.g. Westbury & Keating, 1986; Dalcher, 2008; Napoli et al., 2014; Podesva et al., 2015), we will see that /b/ has an inherent advantage in maintaining voicing over the other places, stemming from the size of the oral cavity and the surface of compliance. First, when producing a /b/, since the tongue is not involved in making the constriction, the oral cavity is relatively large, consisting of the space from the glottis to the lips. In contrast, while producing a /g/, the back of the tongue makes a closure against the velum. As a result, the oral cavity during production of a /g/ is much smaller, consisting only of the space from the glottis to the velum. The /d/ falls in between with the oral cavity being made up of the space from the glottis to the closure of the tongue at the teeth. In smaller spaces, such as in the oral cavity during production of a /g/, air pressure will be higher and will also rise more quickly as air flows in than larger spaces, such as the oral cavity during production of a /b/ (Napoli et al., 2014; Podesva et al., 2015). In other words, the time it takes for supraglottal air pressure to increase to the critical point where voicing will be cut off depends on the place of articulation of the stop and that time is inherently longer for bilabials[12].

Second, labials have a larger surface of compliance than the other places of articulation because the closure does not involve the tongue (Ohala, 1983; Westbury & Keating, 1986). This means that labials are better able to allow expansion of the vocal tract and lengthen the amount of time before oral air pressure would meet subglottal pressure and cut off voicing.

Taking these two things together, although maintaining voicing in stops is difficult, labials have an inherent advantage that stems from the nature of how a labial stop is produced: /b/ has a larger oral cavity, which means that air pressure is lower and increases more slowly, and a larger surface of compliance, which means that the size of the oral cavity can be increased more easily and to a greater extent as compared to other places of articulation. As a result of this advantage, labials need to do less in order maintain voicing. In contrast, stops at other places of articulation need to make greater use of other methods of maintaining voicing, including reducing the degree of closure in order to vent oral air, which reduces oral air pressure and allows greater control in maintaining the differential between subglottal and supraglottal air pressure, resulting in longer voicing (Ohala, 1997)[13].

If maintaining voicing in labial stops is easier than in velars, we would expect that voiced

12 Although, note that Ohala (1983) indicates that the effect of the size of the oral cavity is not as relevant in explaining the asymmetry between labials and other places than the surface of compliance, discussed next.

13 There are other methods of facilitating voicing in stops as well. For one, languages can keep the stop very short. This is reflected in the cross-linguistic tendency for voiced stops to be shorter in duration than voiceless stops (e.g. Luce & Charles-Luce, 1985). See Ohala (2011) for a discussion of methods of circumventing the AVC.

velar stops would be disfavored cross-linguistically as compared to labials. That is, typologically-speaking, languages with a voiced velar stop should be less common than those with a voiced labial stop. In the UCLA Phonetic Inventory Database (UPSID), of the 451 languages in the database, 63.6% have /b/, while only 56.10% have /g/. A chi-square test finds that these two proportions are significantly different ($x^2 = 5.025$, $p = 0.025$, df = 1), indicating that at least within the UPSID, voiced labial stops are indeed more frequent than voiced velar stops.

Napoli et al. (2014) investigated the cross-linguistic pattern of "gapped" systems of voiced stops where one of the places of articulation (labial, dental/alveolar or velar) is missing. They found that 48 languages in UPSID have a system like [b d __], where the velar is missing. In contrast, only 8 languages had a gapped system such as [__ d g] or [b __ g] where the bilabial or dental/alveolar is missing. A chi-square test finds that these two proportions (out of the 451 languages in the UPSID) are also significantly different ($x^2 = 28.959$, $p < 0.0001$, df = 1). In other words, if a language is going to be missing one of the voiced stops, the velar is the most likely one to be missing. Similarly, as discussed in Ohala (1983), in Sherman's (1975) survey of over 570 languages, he found only two languages with a gapped system of voiced stops where the labial was missing, but 40 such systems where the velar was missing[14],[15]. As Ohala notes "[...] it is clear that velar stops and voicing show the greatest incompatibility, labial stops and voicing the greatest compatibility" (Ohala 1983: 195)[16].

As we have seen in this study, Buenos Aires Spanish (BAS) voiced stops at all places of articulation employ the same method of maintaining voicing; that is, they are virtually all realized as approximants in intervocalic position. But, the labial stops were disproportionately realized as the least weakened approximant variant when compared to the dentals and velars. I argue that this pattern is another example of the synchronic and diachronic patterns discussed above and that it can be explained by the fact that labials do not need to weaken as much in order to maintain voicing due to the physiology of producing labial stops as compared to other places.

Hualde et al. (2010) make a similar argument in their account of the asymmetry they found in the lenition of Majorcan Catalan voiced stops in contexts where lenition would be expected, according to the traditional description of the alternation (e.g. Mascaró, 1984). In that study, /b/ was found to lenite to a lesser extent than /d/ and /g/ as determined by two acoustic measures: relative intensity and maximum rising velocity. According to Hualde et al. (2010:72), this asymmetry is often manifested in dialectological transcriptions of Majorcan Catalan by having the labial represented as the stop variant more often than the other places of articulation, which are more often represented as an approximant. The authors argue against an account where /b/ is realized as the stop more often than the other places in order to maintain a phonemic contrast with /v/ (as in Wheeler, 2005). Instead, they appeal to the AVC to explain the pattern. Hualde et al. (2010) note that the AVC was originally intended to explain asymmetries in devoicing of voiced stops by place of articulation, but conclude that a similar explanation can be applied to the spirantization asymmetry in Majorcan Catalan voiced stops, saying "In our interpretation of the AVC, a spirantization process would affect /d/ and /g/ before it affects /b/ for aerodynamic reasons, since [b] offers less aerodynamic difficulties" (Hualde et al. 2010: 76).

As Hualde et al. (2010) show, Majorcan Catalan /b/ is realized as a full stop in lenition con-

14 The apical stop was is the middle with 21 languages having a gapped system missing the apical.

15 I have not provided chi-square tests for the proportions from Sherman's survey because it is not exactly clear what the unique number of languages is that the gapped systems are taken from. However, due to the large difference (2 vs. 40), the difference would likely be statistically significant.

16 Note, however, that some of the statistics in these typological studies may be skewed by areal biases. See Engstrand (1997).

texts more often than the other places. The BAS pattern found in the current study is similar, except that the nature of the variation does not occur between a stop and an approximant, but rather is expressed within the approximant allophone. As we have seen, the majority of the underlying voiced stops in BAS are realized as approximants, irrespective of place; however, /b/ is realized as the least weakened approximant more than the other places. As such, we see the same pattern as found for Majorcan Catalan, but at a more fine-grained acoustic level, within the approximant. Since the voiced stops are more frequently realized as approximants in BAS as compared to Majorcan Catalan, this might suggest that BAS is at a more advanced stage in the historical pattern of lenition of the voiced stops that characterizes the Western Romance languages[17].

What is somewhat less clear is the expected status of /d/. The aerodynamic account predicts that a dental or alveolar voiced stop should show a pattern that is intermediate to the labial on the one hand and the velar on the other. That is, /d/ should weaken more than /b/, but less than /g/. In fact, this was the finding of several of the studies cited above, such as Dalcher (2008) and Lousada et al. (2010). From a typological perspective, Sherman (1975) found that gapped systems of voiced stops were most likely to be missing /g/ and least likely to be missing /b/ with /d/ falling neatly in the middle (see footnote 14 above). However, other studies, such as Hoijer (1933) and Heath (2008), found that /b/ and /d/ patterned similarly, while /g/ was different. Still more studies found that /b/ was least weakened, while /d/ and /g/ pattern together. For example, as discussed in Ohala and Riordan (1979), Bantu languages devoice /d/ and /g/, but not /b/, in the same contexts.

However, these findings are not necessarily in conflict. In all cases, /b/ either maintains its status as a phonetically voiced stop (by avoiding spirantizing and devoicing) the most or does so the most along with /d/. Put another way, in all cases, /g/ loses its status as a phonetically voiced stop the most or does so the most along with /d/. This was the proposal of Foley (1977) in his discussion of the propensity of /b d g/ to spirantize in different languages. There, he proposes a hierarchy where /g/ spirantizes more readily than /d/, and /d/ spirantizes more readily than /b/. He notes that "[...] *g* often spirantizes while *d* and *b* remain, *g* and *d* spirantize while *b* remains, or *g, d, b* all spirantize; but *b* does not spirantize unless also *d* and *g* spirantize, and *b* and *d* do not spirantize unless also *g* spirantizes." (Foley, 1977: 25). Escure (1977) and Wireback (1997) suggest similar hierarchies in which back consonants are more likely to weaken than front consonants[18].

The BAS pattern observed in this study aligns with these hierarchies since /b/ is the least weakened as compared to /d g/. Recall that, as we saw in §3, the pairwise comparisons between /d/ and /g/ were not statistically significant, so from that perspective, it seems that /d/ is not occupying an intermediate position between the labial and the velar. However, there are two pieces of evidence that do suggest some difference in the pattern of lenition for /d/ compared to that of /g/. First, recall that in Table 3, we saw that whereas the open and vocalic variants are equally represented in /g/ (44% each), the most frequent category in /d/ is the open approximant (56%) with the vocalic approximant second most frequent (35%). Although these differences were not

17 See Lewis (2001) for a discussion of how synchronic weakening patterns of /p t k/ in different dialects of Spanish are evidence that the dialects are at different points in a diachronic lenition process.

18 The findings of Colantoni & Marinescu (2010) could be seen as a counterexample to the expected pattern where /b/ lenites the least and /g/ the most. In that study, /d/ was found to lenite the most with 18.4% being deleted altogether, compared to roughly 4.6% for /g/ and 4.1% for /b/. However, although Colantoni and Marinescu included only intervocalic stops, their study included those that were the onset of unstressed syllables, including those found in the past participle suffix *–ado* (as in *hablado* 'speak.past participle'), which is a context where /d/ may be especially susceptible to deletion (Lipski, 2011: 80; Recasens, 2002).

statistically significant, /d/ trends in the direction of leniting to an intermediate degree between /b/ and /g/. It is possible that, with a greater-sized dataset, the differences in patterning between the dental and velar would be significant and we would have stronger evidence for the intermediate position of /d/. Second, the pairwise comparison between the proportions of open and vocalic approximants between /b/ and /g/ was significant, indicating that /g/ is realized as the vocalic approximant more than /b/. Meanwhile, the same comparison was not significant between /b/ and /d/ or, as just mentioned, between /d/ and /g/. From this perspective, /d/ does fall in between /b/ and /g/ since the velar has been shown to weaken to a greater extent only when compared to /b/ and not when compared to /d/. To the extent that these pieces of evidence indicate an intermediate position for /d/ in the degree of weakening between the labial and dental, this would further strength the aerodynamic explanation of the asymmetry by place in this study.

5. Conclusions

To sum up and provide conclusions, although the lenition of Spanish /b d g/ has been considered extensively in the literature, less is known about the effect of the place of articulation and dialect on the degree to which the approximant variant will weaken. This study applied the categorization scheme proposed by Martínez-Celdrán (2004, 2013) to show that in Buenos Aires Spanish, the labial is realized as the least weakened of the spirant approximants significantly more often than the dentals and velars, and the velar is realized as the most weakened variant the most. This asymmetry in the degree of weakening mirrors a common pattern found in synchronic and diachronic studies for a variety of languages in which the labial voiced stop is more resistant to weakening and to devoicing while the velar is the opposite. I argued that this asymmetry can be accounted for by appealing to the Aerodynamic Voicing Constraint (Ohala & Riordan, 1979) and by considering the inherent advantage that labials have in their ability to maintain voicing over more back places of articulation.

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Appendix

Stimuli

following vowel	/b/			/d/			/g/		
/a/	*barco*	/barko/	'boat'	*dama*	/dama/	'lady'	*gato*	/gato/	'cat'
	banco	/banko/	'bank'	*datos*	/datos/	'data'	*gallo*	/gaʃo/	'rooster'
/e/	*beso*	/beso/	'kiss'	*dedo*	/dedo/	'finger'	*guerra*	/gera/	'war'
	bella	/beʃa/	'pretty'	*débil*	/debil/	'weak'	*gueto*	/geto/	'ghetto'
/i/	*vino*	/bino/	'wine'	*dijo*	/dixo/	'said'.3sg.pst	*guía*	/gia/	'guide'
	vida	/bida/	'life'	*dice*	/dise/	'said'.3sg	*guiño*	/giɲo/	'I wink'
/o/	*bote*	/bote/	'boat'	*doble*	/doble/	'double'	*gota*	/gota/	'drop'
	boca	/boka/	'mouth'	*doce*	/dose/	'twelve'	*goma*	/goma/	'rubber'
/u/	*burro*	/buro/	'donkey'	*duda*	/duda/	'doubt'	*gustan*	/gustan/	'please'.3.pl
	buzo	/buso/	'diver'	*dulce*	/dulse/	'sweet'	*gusta*	/gusta/	'please'.3.sg

Percentage of closed, open, and vocalic approximants by place of articulation by speaker

speaker	category	/b/	/d/	/g/
1	closed	33%		5%
	open	67%	87%	65%
	vocalic		13%	30%
2	closed	46%	13%	27%
	open	54%	60%	60%
	vocalic		27%	13%
3	closed	85%	32%	10%
	open	10%	32%	60%
	vocalic	5%	36%	30%

speaker	category	/b/	/d/	/g/
4	closed	50%		10%
	open	44%	76%	35%
	vocalic	6%	24%	55%
5	closed	10%	8%	17%
	open	40%	46%	22%
	vocalic	50%	46%	61%
6	closed	25%		10%
	open	50%	40%	20%
	vocalic	25%	60%	70%