

The Acoustic Realization of the Stop Voicing Contrast in
Argentine Spanish

by

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Abstract

Consonant lenition is a synchronic and diachronic sound change in which consonants become “weaker” or more vowel-like in certain contexts, especially between vowels. Given the variability in how Spanish dialects lenite the voiced stops and given that some varieties of Spanish have been shown to weaken the voiceless stops too, this raises the question of how different dialects of Spanish realize the stop voicing contrast. This thesis explores this issue for Argentine Spanish. This study is based on the corpus data with 9 speakers, 400 recordings containing the 6 stops in intervocalic position. The Acoustic analysis is done in Praat, and relative intensity and percent voicing were measured. The findings indicate that the stop voicing contrast is realized through a combination of relative intensity and percent voice with relative intensity being the stronger of the two cues. Also, place of articulation does not affect the stop voicing contrast in this variety. This study contributes to our understanding of lenition processes and contrast maintenance in varieties of Spanish by illustrating how the stop voicing contrast is realized in one particular variety.

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Chapter 1: Introduction

1.1 Definition of lenition

Consonant lenition is a process by which a consonant segment is realized with a weakened articulation. These changes are most often observed depending on the consonant's position in the word or in certain phonological environments such as next to vowels. Lenition of stops has been explored a lot in the literature. Diachronic stop weakening is documented at various stages as illustrated in the evolution of the intervocalic /t/ in Latin *vita* 'life', to intervocalic /d/ in older Spanish *vida*, becoming modern Spanish *vida* with an intervocalic [ð], and being deleted in modern French *vie*. (Foley, 1977: 25, 34; Lass & Anderson, 1975: 158). There are different approaches to diachronic lenition which have focused on consonant strength hierarchy. Escure (1977) ranked the strength hierarchy based on the articulatory properties of the consonant and the consonant's position in the phonological phrase. According to this hierarchy, voiceless stops are phonologically the strongest followed by voiced stops, followed by voiced fricatives, with deletion at the weakest end. This means that lenition involves a shift towards the weaker end. Therefore, voiceless stops becoming voiced is an instance of consonant lenition. She also suggests that the most vulnerable environment prone to lenition is word final position followed by word medial. Also, back consonants like velars are more likely to weaken and delete than front ones.

Stop lenition is one of the most frequently discussed phonological processes in Spanish. Diachronic lenition in Spanish shows that consonant weakening started as a chain of changes in Latin geminate stops (all of which were voiceless) to singletons, voiceless to

voiced, voiced to approximants and approximants to \emptyset (Martinet, 1952). This process can be shown for Spanish stops as following:

/pptkk/ → /ptk/ → /bdg/ → /βðɣ/ → \emptyset

Voicing happens when a voiceless consonant becomes voiced. Spirantization refers to the realization of a voiced consonant as a fricative in a context where the consonant is surrounded by vowels. Consonant deletion happens when the production of the lenited consonant is lost and it completely assimilates to its surrounding vowels.

In addition to this diachronic change, Spanish stops also lenite synchronically. Recent research on Spanish lenition is mostly focused on the voiced stops and previous research has found that lenition affects the stop consonants in intervocalic positions more often than in other positions and it causes them to lenite to a greater extent (Carrasco, Hualde & Simonet 2012; Colantoni & Marinescu, 2010; Cole, Hualde & Iskarous, 1999; 1999; Eddington, 2011; Ortega-Llebaria, 2004). However, studies have shown that the voiceless stops may lenite, too (Colantoni & Marinescu, 2010; Hualde, Simonet & Nadeu, 2011; Lewis, 2001). Even though the recent studies to be discussed in the next sections provide valuable findings on lenition in different Spanish varieties, they do not focus on variation of both voiced and voiceless stops at the same time. More works on consonant lenition focus only on either /ptk/ or /bdg/, and sometimes even only on one or two consonants of these series. The gap in current research on the lenition of stops in Spanish motivates the need for the acoustic analysis and evaluation provided in my thesis.

1.2 Lenition of /ptk/ and /bdg/

There is a voicing contrast between the voiceless Spanish stops /ptk/ and their voiced counterparts /bdg/. According to the traditional view, Spanish /bdg/ have allophones

of stops and approximants in complementary distribution. The voiced stops are realized as approximants after vowels, rhotics, glides and laterals (except for /d/ which remains full stop after laterals), and as full stops in other environments (Harris, 1969; Lozano, 1978; Mascaró, 1984, 1991; Navarro Tomás, 1918). Some examples are shown in Tables 1 and 2.

/kabo/	[ka.β̞o]	‘cape’
/dedo/	[de.ð̞o]	‘finger’
/lago/	[la.ɣ̞o]	‘lake’

Table 1. /bdg/→[β̞ð̞ɣ̞]

/bomba/	[bom.ba]	‘bomb’
/falda/	[fal.da]	‘skirt’
/grande/	[gran.de]	‘big’
/ganga/	[gaŋ.ga]	‘bargain’

Table 2. /bdg/→[bdg]

However, experimental research and acoustic works have challenged the traditional understanding of lenition and show that there is a lot of variation in how the voiced stops are lenited across dialects of Spanish (Carrasco et al., 2012; Colantoni & Marinescu, 2010; Cole et al., 1999; Eddington, 2011; Ortega-Llebaria, 2004). For example, Mexican Spanish /bdg/ are produced with greater occlusion even in intervocalic position whereas the same segments in some Peninsular and Caribbean varieties are much more open, with /bdg/ often experiencing total deletion (Butera, 2018). Also, some studies on several dialects of Spanish have documented that intervocalic /ptk/ may voice and spirantize, making [ptk], [bdg], and [β̞ð̞ɣ̞] all possible pronunciations. For example, Hualde, Simonet & Nadeu (2011) examined the lenition of intervocalic voiceless stops in Spanish of Spain and found that a third of all tokens of intervocalic /ptk/ are fully or partially voiced in spontaneous

speech. In the dialects where there is weakening of voiceless stops, the way the contrast is maintained could be changing.

The fact that the lenition of voiced stops varies in different dialects can influence how the contrast between the voiced and voiceless stops is realized. Although many studies have focused on lenition in Spanish voiced stops, not many have investigated the process of weakening in Spanish voiceless stops and few studies have looked at the contrast between the voiceless and voiced stops and how the contrast is being realized. Also, there are few studies which are dedicated to both lenition processes in the same variety of Spanish (but see Butera, 2018).

1.3 Research questions

This paper discusses the connection between the voicing contrast and lenition of voiced and voiceless stops in intervocalic position. Given the variability in how Spanish dialects lenite the voiced stops and given that some varieties of Spanish have been shown to weaken the voiceless stops too, this raises the question of how different dialects of Spanish realize the stop voicing contrast. The current study explores this issue for a particular variety of Spanish: Argentine Spanish. Therefore, my thesis investigates the following research questions:

- 1- How is the stop voicing contrast of Argentine Spanish realized in intervocalic position?
- 2- Does place of articulation influence which acoustic cues are used to produce the contrast?

Chapter 2: Background

2.1 Spirantization

2.1.1 Traditional description

According to the traditional phonological description of spirantization, Spanish /bdg/ has allophones of stops and approximants¹ in complementary distribution. Previous studies have shown that the voiced stops are mostly spirantized or weakened in different positions such as after vowels, rhotics, glides and laterals (except for /d/ which remains full stop after laterals), and they remain stops in all other environments (Harris, 1969; Lozano, 1978; Mascaró, 1984, 1991; Navarro Tomás, 1918):

/bdg/ → [βðɣ] after vowels, glides, rhotics, laterals (except for /d/)
→ [bdg] elsewhere

According to this classification, as a phonological rule, speakers of Spanish produce either the stops or approximants depending on the surrounding segments. However, there are other factors that influence the lenition of voiced stops to different degrees.

2.1.2 Experimental work and degree of weakening

Experimental studies have shown that voiced stops vary in their degree of lenition depending on factors such as stress, position in word and the surrounding context (Carrasco et al., 2012; Colantoni & Marinescu, 2010; Cole et al., 1999; Eddington, 2011; Ortega-Llebaria, 2004). The effect of stress has been consistent among previous studies (Cole et al., 1999; Ortega-Llebaria, 2004; Eddington, 2011). They have found that voiced stops weaken less when they are the onset of a stressed syllable, and they weaken more when

¹ Early work on spirantization in Spanish assumed the continuant allophones were fricatives [βðɣ], but experimental work showed them to be approximants (Martínez-Celdrán, 1984; Romero, 1995). However, the tradition of calling it spirantization and using the fricative symbols has persisted.

they are the onset of an unstressed syllable. However, the effect of the surrounding contexts has not always been consistent in experimental studies. Cole et al. (1999) found that the voiced velar /g/ exhibits the greatest degree of weakening with adjacent vowels /o/ and /u/. The results from Ortega-Llebaria (2004) also showed that vowel context has a significant effect on the degree of spirantization in intervocalic consonants in English and Spanish. /g/ was more lenited when it was next to vowels /i/ and /u/ and less lenited next to /a/. That study also examined the realization of /b/ in intervocalic position, without finding an effect of vowel height in this case.

In another study, Simonet et al. (2012) analyzed intervocalic /d/ and found that the height of the preceding vowel conditions the degree of constriction of the consonant. They report that in Iberian Spanish /d/ is more constricted after a high vowel than after a mid or low vowel. The results of these studies show that there seems to be an effect of surrounding vowel on degree of lenition but this effect is far from clear.

Another important factor in lenition is place of articulation which could complicate the effect of the surrounding vowels. Previous studies have found that stops lenite to different extents by place of articulation. Colantoni & Marinescu (2010) found that the quality of the vowel affected /bdg/ differently and clear place asymmetries emerged from their results: /d/ lenited the most and had a higher rate of deletion when preceded by /a/ or /e/. They explained this asymmetry by the predictions of models of coarticulation which assume that the size and direction of coarticulatory patterns vary according to the articulatory requirements involved in the production of different vowels and consonants. However, many studies have not included all 3 places of articulation and only looked at a subset of these places. For example, Cole et al. (2009) only looked at /g/, Ortega-Llebaria

(2004) investigated /b/ and /g/ and Simonet et al. (2012) only intervocalic /d/. This makes it difficult to glean clear findings of place of articulation on the pattern of lenition.

2.2 Dialectal variation

Among the varieties of Spanish, there is a lot of variation in terms of the pattern of lenition. Innovative dialects show a higher degree of consonant lenition, sometimes to the point that the voiced stops disappear completely, whereas conservative varieties exhibit the production of full stops even in the right environments for lenition. Carrasco et al. (2012) worked on Costa Rican and Madrid varieties and found that Costa Rican Spanish shows more conservative productions of /bdg/, as opposed to higher level of weakening found in Madrid Spanish. Lewis (2001) also showed that dialects in Northern Spain which are more innovative, show extensively more consonant weakening than the Colombian Spanish. Canfield (1960, 1963: 77–78, 1981) also found that /bdg/ remain stops after semivowels, /l/, /r/, and /s/ in much of Central America (El Salvador, Costa Rica, Honduras, and Nicaragua), and in highland Colombia. Canfield (1963: 78) affirms that in the highlands of Ecuador and Bolivia, /bdg/ are occlusive after /s/. Lipski (2011:80) suggested that in all these dialects, voiced stops tend toward full stop pronunciation in all postconsonantal contexts. Consequently, dialectal variation in lenition of voiced stops can affect the way the voicing contrast is realized. That is to say that in the dialects where the weakening of voiceless stops is found, the contrast between voiced and voiceless stops could be changing.

2.3 Voiceless stops

Researchers have shown that voiceless stops also lenite in intervocalic position and they become voiced stops or voiced approximants. Voiceless stop weakening has been

found in different varieties of Spanish such as in Spain, and several varieties of Latin American Spanish. However, the amount of research on lenition of voiceless stops is much less than that for voiced stops.

Lewis (2001) compared intervocalic voiceless stops in the Spanish of Northern Spain (expected to be an innovative variety) and Central Colombia (expected to be a conservative variety). He used three acoustic measurements: closure duration, voice onset time (VOT) and relative intensity (RI). With respect to closure duration, voiceless velars weakened more than alveolars and labials, whereas voiceless labials lenited more than alveolars in VOT. The results for RI did not suggest any influence of place of articulation on the pattern of weakening. His findings suggest that the Northern Spanish dialect shows higher degrees of lenition of /ptk/ than the Central Colombian dialect and the voiceless stops in intervocalic position are frequently realized as voiced approximants in spontaneous speech. Moreover, the surface realizations of the two stop consonant series in Northern Spanish had potential for overlap:

/ptk/ → [ptk] , [bdg] , [βðɣ] or [β̞ð̞ɣ]

/bdg/ → [bdg] , [βðɣ] , [β̞ð̞ɣ] or [∅]

As it is shown above, depending on different independent variables, the voiceless stops could surface as voiceless stops, voiced stops, voiced fricatives or voiced approximants. Similarly, the voiced stops could surface as voiced stops, voiced fricatives, voiced approximants or could be highly lenited and deleted.

Hualde, Simonet & Nadeu (2011) compared intervocalic voiceless stops in the Spanish of Mallorca. In semi-spontaneous speech, one third of their data showed complete

or partial voicing of /ptk/. Also, their results revealed that /ptk/ could produce surface variants that are voiced with [+continuant] feature.

Colantoni & Marinescu (2010) also investigated weakening of intervocalic voiceless and voiced stops in speakers of Argentine Spanish. They measured the total duration, relative intensity, and the percentage of the consonant duration. Among voiceless stops, place asymmetries were not found and the differences in places of articulation were not significant. They also found that /ptk/ did not undergo a high degree of voicing. Therefore, it can be said that in those varieties of Argentine Spanish, the contrast between the voiced and voiceless stops was preserved.

There is a lot of dialectal variation on how much the voiced stops lenite which can influence the voicing contrast. Lenition of voiceless stops could be expected to exist in dialects that have weakening of voiced stops. If the more innovative dialects also exhibit the higher degree of weakening in voiceless stops, the contrast could be changing. The changes in the voicing contrast might happen due to the pull-chain shift which occurs when a certain segment suffers weakening or loss in a certain phonetic environment, leaving empty slots in the phonological inventory (Martinet, 1952; Veiga, 1988).

The goal of the current study is to contribute to our understanding of how different dialects of Spanish that have lenition of voiceless stops maintain the contrast.

2.4 Acoustic correlates

Acoustic variables such as relative intensity, percent voicing, VOT and duration may provide evidence of consonant lenition. Relative intensity and percent voicing were measured in this study, and they are explained in §3, however, as it is mentioned in the previous section, many studies have also measured VOT and consonant duration. VOT is

used in the comparison of voiceless and voiced stop consonants in absolute initial position (Lewis, 2001) and the role of VOT is less clear in intervocalic position. This acoustic correlate differentiates between voiced and voiceless stops by fixing attention on the timing relation between voice onset and the release of occlusion. VOT is not a relevant correlate for this study since the position of the target consonants in the current study is word-medial intervocalic. Moreover, VOT does not show the extent of lenition especially in voiced stops.

Another acoustic variable used to compare the voiced and voiceless stops is duration. In intervocalic position, the productions of /bdg/ have approximant realizations instead of occlusive realizations which makes segmentation difficult (Figueroa and Evans, 2015). Several studies such as Colantoni and Marinescu (2010) have used this measurement despite this methodological problem, but it is not always clear how their manual segmentation has been executed. Therefore, relative intensity and percent voicing are the two acoustic cues measured in the current study. While segmentation is also required for percent voicing, it is not methodologically problematic since the most difficult tokens to segment are the ones with 100% voicing.

2.5 Argentine Spanish

The consonant phoneme inventory of the variety of Argentine Spanish is described in Table 3 below (Coloma, 2018). Argentine Spanish shares a lot of similar characteristics with other varieties of Spanish. It has 5 vowel phonemes: /a, e, i, o, u/ and like many other dialects, it has *yeísmo*: the sounds represented by *ll* (palatal lateral /ʎ/) and *y* (the palatal

approximant /j/) have merged into one. In Argentine Spanish, this merged phoneme is pronounced either /z/ or /ʃ/.

There are several dialectal variations within Argentina. Coloma (2018) divides the dialects into four areas: the Northwest, Northeast, West and the dialect of Buenos Aires which is the most influential variety in Argentina.

	Labial		Dental/ Alveolar		Palatal	Velar		Glottal
Plosive	p	b	t	d		k	g	
Affricate					ʧ			
Nasal		m		n		ɲ		
Tap				r				
Trill				r				
Fricative	f		s		ʃ		x	
Lateral				l				

Table 3. Consonant Chart of Argentine Spanish. Adapted from Coloma (2018)

Previous research on lenition of stop consonants in Argentine Spanish has found lenition of voiced stops in this dialect. For example, Colantoni & Marinescu (2010) found that target voiced stops were consistently realized as approximants and some of the voiced tokens were deleted, and there were fewer signs of weakening in the voiceless stops.

There is not a lot of research on lenition in Argentine Spanish and not much is known about how the voicing contrast is realized in this variety. This is not only due to a

lower number of studies, but also from different methodology. This study explores how Argentine Spanish realizes the stop voicing contrast. It also compares the lenition of voiced and voiceless stops and investigates if the place of articulation plays a role on lenition in this variety.

Chapter 3: Methodology

3.1 Materials

The present study is based on corpus data and the *Romance Phonetics Database* (Colantoni, L., & Steele, J. (2004) *The University of Toronto Romance Phonetics Database* <http://rpd.chass.utoronto.ca/>) was used as the source of data. This database contains 5 different corpora with tagged sound samples (both individual words and passages) which illustrate different aspects of Romance phonetics and phonology. The corpus particularly used in this study is called the *Linguistics Atlas of Argentina* and the data were collected by Laura Colantoni in Argentina from 1994 to 1997. The speakers are 49 men and 46 women ranging from 25 to 65 years of age at the time of participation in the study. All participants were born and lived in the locations under study, and they mostly had elementary education or less. Interviews ranged from 1 to 3 hours and included vocabulary elicitation plus short narratives and were recorded in a variety of locations.

In order to query the database, there are varieties of values which can be selected from the lists of variables. I preferably wanted to control for the voiced and voiceless stops in intervocalic position and the nature of the surrounding context. Intervocalic position is one of the most favorable environments for lenition to happen (e.g., Hyman, 1985) given the sonorous quality of the vowels on each side (VCV) and the assimilation processes of the consonants to become more vowel-like when in this position. As mentioned in the background section, the nature of the vowels in the surrounding context can also influence the degree of lenition (Carrasco et al., 2012; Cole et al., 1999).

As the corpus was based on spontaneous speech, the target words were only roughly balanced for place of articulation of the target consonants /ptk/ and /bdg/ and as a result the number of the stop consonants were not even. In particular, there were fewer words with word-medial /p/. The stress position was post-tonic and post-post-tonic, therefore the vowel following the target consonant was unstressed. In this way more lenition could be expected (Colantoni & Marinescu, 2010; Cole et al., 1999; Ortega-Llebaria, 2004). The segment preceding the consonant was the vowels /a,e,i,o,u/ and they were somewhat balanced between front /i,e/, back /u,o/ and low /a/ vowels. There were roughly equal numbers of tokens with the vowel preceding the stop consonants from each of the three vowel classes: front vowels /i,e/ (172), back vowels /u,o/ (71) and low vowel /a/ (157). The main reason for classifying the preceding phonemes as front, back and low vowels was that in this way, each target consonant could have one of the vowel groups as its preceding contexts. Moreover, the effect of both of the front vowels and back vowels in each group was previously suggested to be mostly similar (Cole et al., 1999).

The segment following the target consonant was restricted to the low vowel /a/, as it was difficult to balance by following vowel. Therefore, to avoid confounding the effects of place of articulation and following vowel, I only included words with /a/ following the target consonant since that was the most frequent following vowel. Carrasco et al. (2012) also used the same method in their study. They argued that the traditional phonological analysis of Spanish spirantization depends on the preceding context only.

The query resulted in 260 words in total, some appearing multiple times with the total of 400 recordings spoken by 9 Argentine Spanish speakers (3 females, 6 males) ranging in age from 34 to 57. The speakers were from the two provinces of Corrientes and

San Juan. Corrientes is located in the northeast of Argentina, and it is about 1000 km from Buenos Aires. San Juan is in the west of Argentina and has a border with Chile. In the current study, each variety has not been looked at separately, however, previous studies reported a more advanced stage in the weakening of voiced stops in Corrientes than in San Juan (Vidal de Battini, 1964, as cited in Colantoni & Marinescu, 2010).

Target words contained voiced or voiceless intervocalic stops in the onset of an unstressed syllable with distribution by phoneme and the preceding vowel in table below.

Preceding Vowel	Voiced Stops			Voiceless Stops			Following Vowel
	/b/	/d/	/g/	/p/	/t/	/k/	
/i, e/	28	25	41	0	41	37	/a/
/u, o/	8	18	4	11	8	22	
/a/	54	58	8	6	20	11	
total	90	101	53	17	69	70	

Table 4. Distribution of target phonemes and preceding vowels

In the corpus, all the intervocalic /ptk/ and /bdg/ were manually segmented in Praat (Boersma & Weenink, 2022). The segments were determined by looking at the waveform, formants and the intensity and listening to the recordings repeatedly. For voiceless stops, the beginning of the consonants was marked at the end of the periodic cycles of the preceding vowels and the offset of the consonant was marked where the periodic cycles of the following vowel began. The same procedure was done for the voiced stops with clear boundaries (Figure 1).

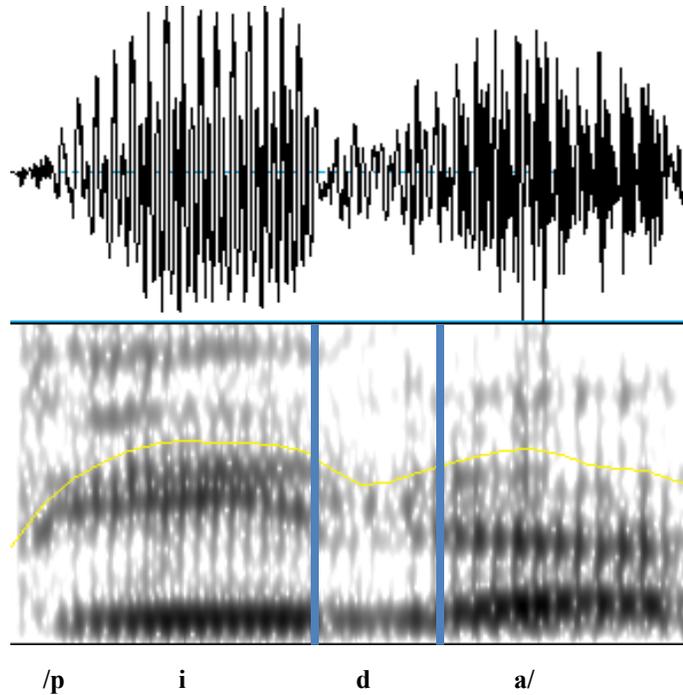


Figure 1. Onset and offset of /d/ in the word *pida* 'request'

However, the majority of the cases were not as clear as what is shown in Figure 1. Marking the precise onset and offset of the voiced stops that have lenited is difficult due to the similarity of the voiced stops in the spectrogram to the surrounding vowels (Figure 2). The oval seen in Figure 2 was added to show the approximate location of the stop, which contains the intensity dip, but the precise onsets and offsets could not be identified since the formants continue throughout the stop and there are no obvious boundaries. As a result, I had to rely on the intensity curve where a slight dip was seen between the vowels for voiced stops (MacLeod, 2020; Martínez-Celdrán, 2004, 2013). In cases where the formants were still visible and the intensity did not dip relative to the surrounding vowels, I decided that complete deletion had happened (Colantoni & Marinescu, 2010). There was a total number of 38 tokens which 29 of them were voiced stops /d/, 8 /b/ and only 1 voiced velar /g/. Cases of complete deletion were not considered in the current study (Figure 3).

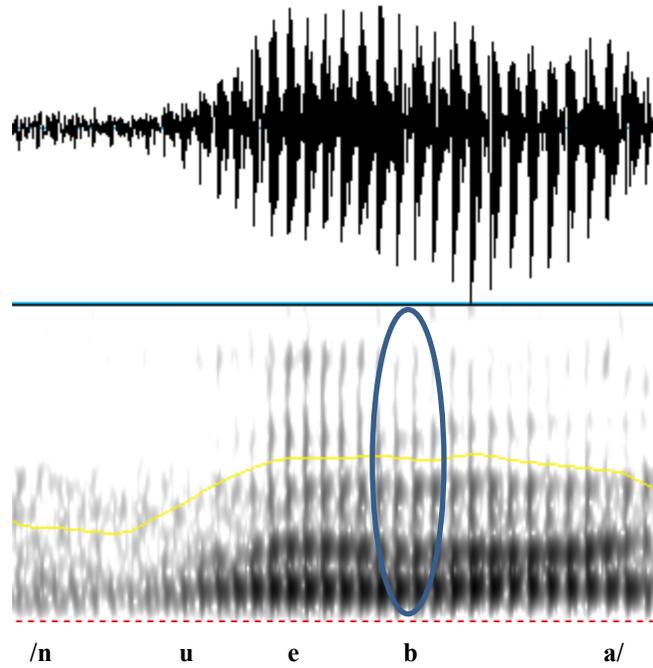


Figure 2. Spectrogram of the word *nueva* 'new'. Notice the highly lenited /b/.

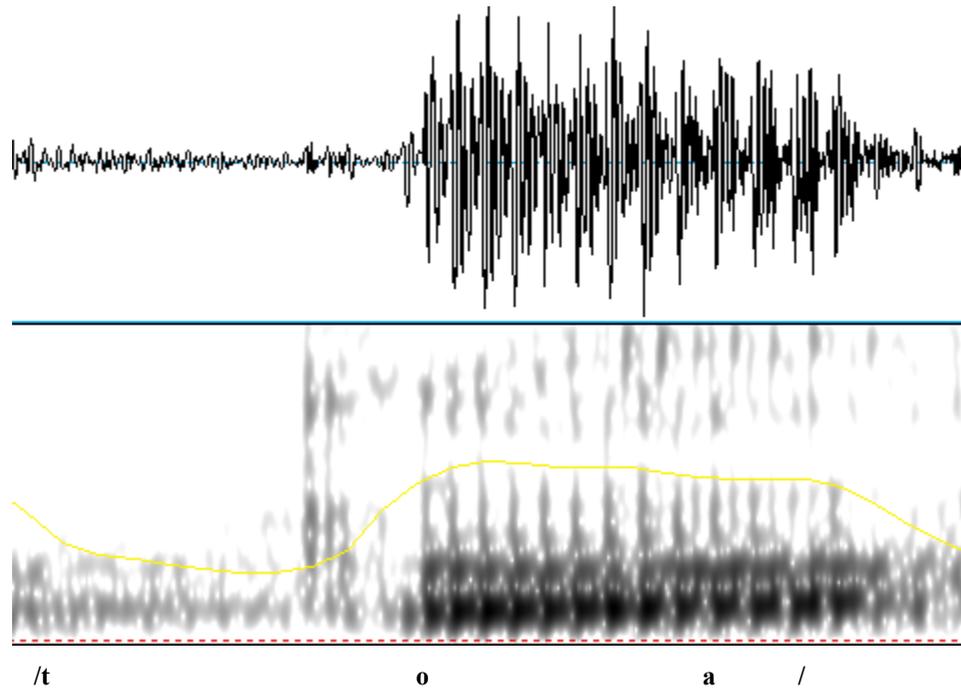


Figure 3. Spectrogram of the word *todas* 'all' as an instance of total deletion of /d/.

3.2 Acoustic measurements

Two acoustic correlates were measured using Praat: relative intensity and percent voicing. None of these measurements were done manually and they were all analyzed with a Praat script.

3.2.1 Relative intensity (RI)

Relative intensity of a consonant is the difference in decibels (dB) between the minimum intensity of the consonant and the maximum intensity of the following vowel. I measured RI for both voiced and voiceless stops and made two predictions based on existing literature. First, voiced stops are predicted to have higher RI (i.e. intensity closer to following vowel) than voiceless stops. Second, the degree of lenition is predicted to be reflected in RI, with more lenited stops having higher RI than less lenited stops (Soler & Romero, 1999; Cole et al., 1999; Lavoie, 2001; Ortega-Llebaria, 2004; Villafaña Dalcher, 2006). Figures 4 and 5 include Praat images of a voiceless and voiced consonant /p/ and /d/, respectively. These images show the Praat spectrogram as well as the yellow intensity curve of two words extracted from the data set. The first arrow on each image indicates the lowest point of intensity in the consonant, whereas the second arrow shows the peak in intensity of the following vowel. The Praat script measured the difference between the minimum intensity of the stop consonant and maximum intensity of following vowel.

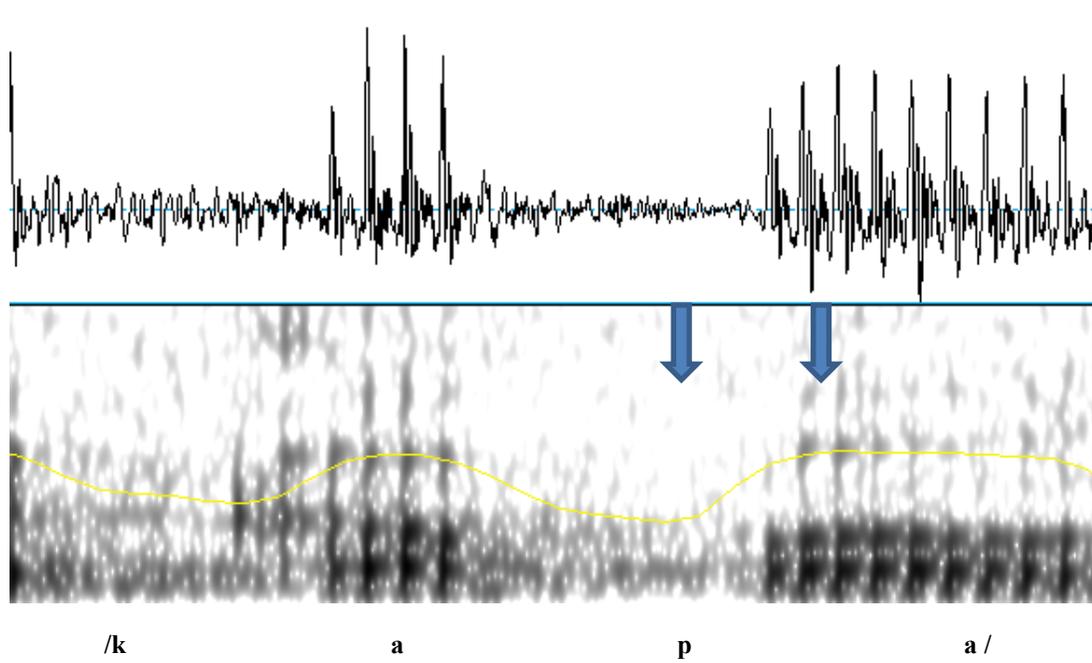


Figure 4. Relative intensity of the word *capa* /'ka.pa/ 'cape'

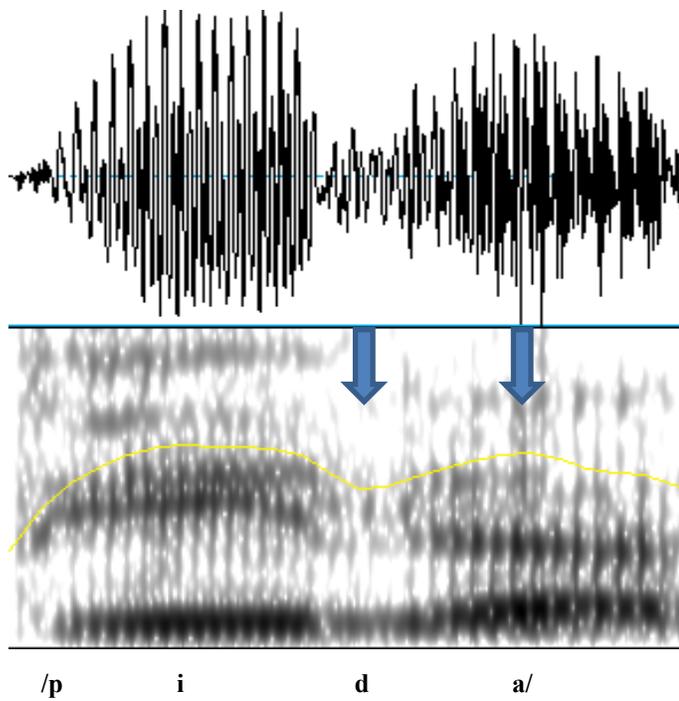


Figure 5. Relative intensity of the word *pida* /'pi.da/ 'request'

If the contrast is robustly realized, I would expect to see a large difference in RI between the voiced and voiceless stops with no overlap. If the voiceless stops are weakening as well as the voiced stops, then I would expect the RI of both stops to be closer to each other with even overlap between /ptk/ and /bdg/ and as a result, that would affect the voicing contrast. Place of articulation might also have an effect on the degree of weakening (Carrasco et al., 2012; Cole et al., 1999; MacLeod, 2020). Due to the Aerodynamic Voicing Constraint (Ohala & Riordan, 1979), maintaining voicing in voiced velars is predicted to be more difficult than in other places of articulation. Therefore, there might be differences in RI at different places of articulation.

3.2.2 Percentage voicing (%V)

The second acoustic measurement is percentage voicing (%V) which is the percentage of the stop in which there is phonetic voicing, and it is measured using the voice report function in Praat. As /bdg/ are voiced segments, their percent voicing is expected to be higher and closer to 100%. Voiceless stops are expected to have lower percent voicing and closer to 0%. On the other hand, if the voiceless stops weakened, their %V will increase. Previous studies used a 60% threshold to determine the %V of /ptk/ (Hualde et al., 2011; O'Neill, 2010). That is, they considered the stops to be voiced if %V was 60% or higher. There are other studies which have used the binning categorization. Davidson (2016) classified each obstruent as voiced when greater than 90% of the interval was identified as voiced by Praat Voice Report, unvoiced when less than 10% of the interval was identified as voiced or partially voiced when between 10% and 90% of the interval was voiced. She argues that to not exclude cases from being fully unvoiced or voiced by just one glottal pulse, she used this classification instead of 0% and 100%.

I took a similar approach to Davidson's (2016). However, as her median category (10% to 90%) was too wide to be considered as partially voiced, I categorized each token by percent voicing in 3 bins in this study: 0-25% as completely voiceless, 76-100% as fully voiced and 26-75% is somewhere in the middle.

Chapter 4: Results

This chapter presents the results of data analyses as well as interpretations of statistical tests on the data set. This chapter is divided into two main sections: relative intensity (RI) and percent voicing (%V).

4.1 Relative intensity (RI)

The box plot in Figure 6 indicates RI of the voiced and voiceless stops by three places of articulation: labial, alveolar and velar. The plot shows that the voiced stops (red boxes) have higher relative intensity (i.e., more similar to the following vowel; RI is closer to 0) than the voiceless stops (blue boxes). The two Praat spectrograms in Figures 4 and 5, displaying yellow intensity curves, clearly displayed the contrast presented in Figure 6 by showing the RI differences between the voiced and voiceless stop. As it goes from voiced to voiceless stops, the RI drops in all three places of articulation and it varies from 0 to -20 dB. The contrast between the voiced and voiceless stops is substantial with only little overlap in the whiskers and not the main boxes. The plot also shows the influence of RI on voicing in alveolars and velars which is not consistent with what was expected in velars. Unlike what was expected, voiced velars have slightly lower RI than alveolars, making the distinction between voiced and voiceless velars somewhat less than other places.

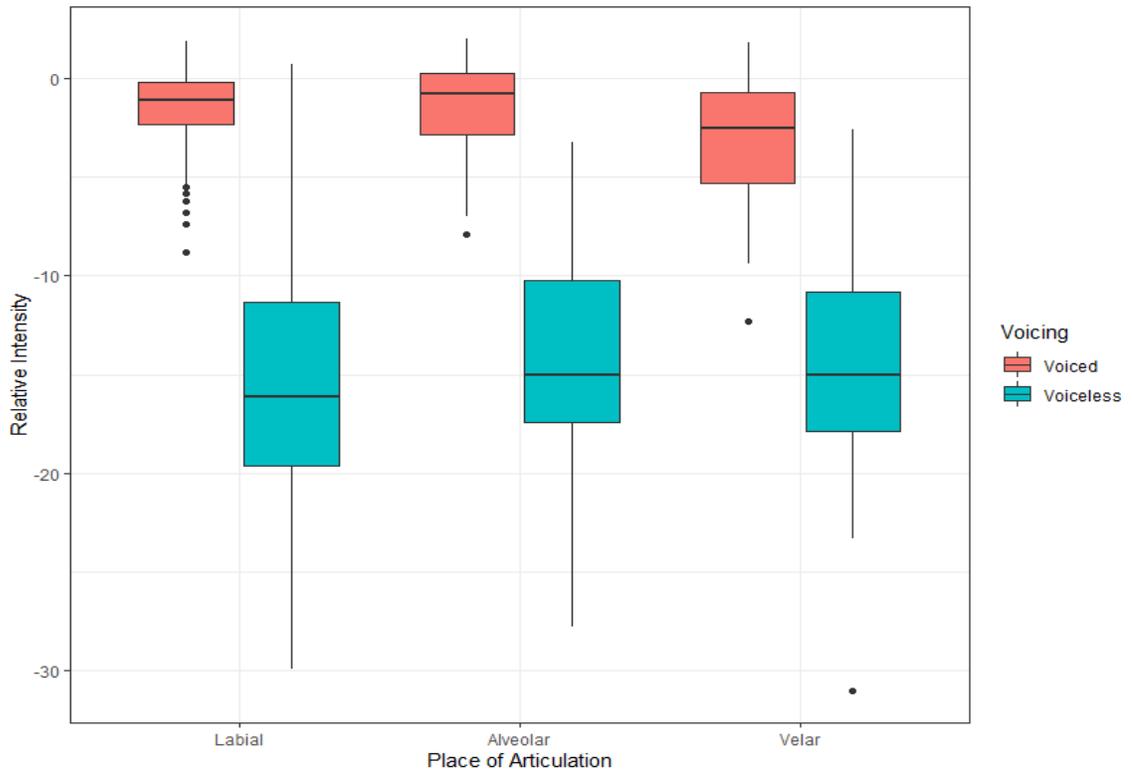


Figure 6. Box plot showing RI by place and voicing

4.2 Percent voicing (%V)

As discussed in previous chapters, Spanish voiced stops are expected to have higher percent voice and voiceless stops lower by nature. I categorized each token by percent voicing in 3 bins: 0-25% as completely voiceless, 76-100% as fully voiced and 26-75% is somewhere in the middle. The results of percentage voicing for the target consonants are shown in Table 5. For the voiced tokens, 85% of them are fully voiced and only less than 6% of them are completely voiceless. For example, 79% of voiced labials /b/ are fully voiced and only 5% of them are completely voiceless. The table also shows that only 5% of the voiceless tokens are fully voiced and around 80% of them are completely voiceless.

	Voiced			Voiceless		
	%V	Freq	Num	%V	Freq	Num
labial	76-100%	79%	71	76-100%	6%	1
	26-75%	16%	14	26-75%	12%	2
	0-25%	5%	5	0-25%	82%	14
alveolar	76-100%	87%	88	76-100%	6%	4
	26-75%	7%	7	26-75%	19%	13
	0-25%	6%	6	0-25%	75%	52
velar	76-100%	89%	47	76-100%	3%	2
	26-75%	2%	1	26-75%	13%	9
	0-25%	9%	5	0-25%	84%	59

Table 5. Percentage voicing in /ptk/ and /bdg/

4.3 Statistical Analysis

Overall, as it was seen in the results of RI and %V, both acoustic correlates show that the contrast between voiced and voiceless stops is maintained and there is no significant overlap. However, to answer the research questions and to see the statistical significance of the results of my study, the results were analyzed by a statistical model to determine how much these two measurements contribute to lenition and also to find their interactions by place of articulation. A logistic mixed-effects analysis was built in R (R Core Team, 2021) using the `glmer()` function in the *lme4* package (Bates, Mächler, Bolker & Walker, 2015). Voicing (voiced vs. voiceless) was the dependent variable, with word

and speaker as random effects, and RI and %V as well as their interaction by place of articulation as fixed effects. The syntax of the model is shown below: the reference level for place of articulation in this model was alveolars and both RI and %V were scaled.

```
glmer (voicing ~ 1 + relative intensity + relative intensity:place + percent voice +
percent voice:place + (1|word)+(1|Speaker)
```

This model found that stop voicing was strongly predicted by both relative intensity ($\beta = -30.1$, $p < 0.001$) and %-voicing ($\beta = -18.7$, $p < 0.001$). Also, there was a significant interaction between relative intensity and place of articulation which showed that the distinction between voiced and voiceless stops was smaller in velars as to compared to alveolars ($\beta = 35.5$, $p < 0.05$).

	β-Value	z-Value	p-Value
Relative intensity	-30.13	-3.617	<0.001
Percent voice	-18.67	-3.679	<0.001
Relative intensity:	-2.03	-0.104	
labial			
Relative intensity:	35.48	2.179	<0.05
velar			
Percent voice: labial	4.85	0.608	
Percent voice: velar	5.64	0.814	

Table 6. Output of Mixed Effects Regression Analysis

These findings suggests that both acoustic measures contribute to the contrast at least in production and unlike what was expected, the difference in relative intensity

between voiced and voiceless stops is somewhat smaller in velars as compared to alveolars but there is no asymmetry by place in percent voice.

Chapter 5: Discussion

This study examined the acoustic realization of the stop voicing contrast in Argentine Spanish. This chapter offers a discussion of the findings of the acoustic analysis of the stop consonants /ptk/ and /bdg/ by looking at the acoustic correlates used in this study: relative intensity (RI) and percent voicing (%V). The results obtained from both RI and %V were analyzed by a statistical model.

The remainder of this chapter discusses the summary of findings in §5.1, and in §5.2, I explain the findings by phonetic and phonological effects (§5.2.1) and relating to dialectology and sociolinguistics in (§5.2.2).

5.1 Summary of findings

Recall the two research questions below:

- 1- How is the stop voicing contrast of Argentine Spanish realized in intervocalic position?
- 2- Does place of articulation influence which acoustic cues are used to realize the contrast?

The boxplot in Figure 6 suggested that the voicing contrast in Argentine Spanish was well maintained since there was no evidence of much overlap between the voiced and voiceless stops in either RI or %V. The statistical analysis confirmed this, showing that both acoustic measures contributed to the distinction between voiced and voiceless stops. Also, the difference in relative intensity between voiced and voiceless stops was somewhat smaller in velars as compared to alveolars but there was no asymmetry by place in percent voice.

5.2 Implications of findings

5.2.1 Phonetic and phonological effects

The linguistic factors used in this study show significant effect on lenition of voiced and voiceless stops in Argentine Spanish. Both RI and %V found that the intervocalic realizations are less lenited for voiceless stops than voiced stops. The main motivation for the current study was to better understand to what extent the voiceless stops weaken in Argentine Spanish and whether such weakening influences the way the voicing contrast is realized. Previous studies looked at several varieties of Spanish and have found that the voiceless stops weaken to different degrees (Colantoni & Marinescu, 2010; Hualde et al., 2011; Lewis, 2001; among others) which could have meant that the contrast between the voiced and voiceless stops was changing. For example, Hualde et al. (2011) showed that 22% of all tokens of intervocalic /ptk/ in spontaneous style are fully voiced in Peninsular Spanish. Rogers & Mirisis (2018) also worked on lenition of the voiceless stops in the Spanish of Concepción, Chile and found that lenition of /ptk/ is more advanced and present in their study compared to similar previous ones on different varieties. Their findings also suggest that even though intervocalic /ptk/ were not lenited as much as /bdg/, compared to the levels of lenition reported for intervocalic /ptk/ in other varieties of Spanish, the voiceless stops undergo much greater levels of lenition. Lewis (2001) also found high levels of weakening of voiceless stops in Spanish of Northern Spain. He also suggested that the surface realizations of the two stop consonant series in Northern Spanish have potential for overlap.

However, in contrast to these findings, the current study shows no evidence of lenition of voiceless stops or threat to the contrast in Argentine Spanish. This points out

that there seems to be variation between the dialects in how the voiceless stops weaken in the same way that there is variation in how the voiced stops weaken. Although Argentine Spanish is a fairly leniting dialect and has weakening of voiced stops (Colantoni & Marinescu, 2010) and it might be expected to see more lenition in voiceless stops in dialects that weaken voiced stops more, my study did not find a lot of lenition in voiceless stops which is in fact consistent with what Colantoni & Marinescu (2010) found in their study. To date, not many studies have explored lenition of both the voiced and voiceless stops together (but see Lewis, 2001) and how their realization affects the realization of the voicing contrast in Spanish. This highlights a potential area for more work since there are lots of dialects that have not been looked at for how the contrast is realized.

It was mentioned before that the Aerodynamic Voicing Constraint (AVC) affects voiced stops and causes asymmetries among them in terms of the extent to which they weaken (Ohala & Riordan, 1979). The AVC has long been recognized in phonetics-phonology. MacLeod (2020) explains the cause of these asymmetries explicitly in her study:

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. 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 (112).

Among voiced stops /bdg/, it is typically /g/ that weakens most or is often missing from the series. Labials have the advantage of maintaining voicing longer than the other two places of articulation due to larger cavity volume and /d/ falls somewhere in between in this category. Based on this, more lenition in voiced velars as compared to labials and alveolars was anticipated. These asymmetries were shown in previous studies. Carrasco et al. (2012) found that, in Costa Rican Spanish, /g/ is weaker than /b/ and /d/ in postconsonantal position. Their results were consistent with Hualde and Nadeu (2012) for Rome Italian where they found that Italian intervocalic voiced alveolars and velars tend to lenite more than voiced labial. Similarly, Hualde et al. (2010) showed that /b/ lenites less than /d/ and /g/ in Majorcan Catalan. Also, MacLeod (2020) found that in Buenos Aires Spanish, all places of articulation maintain voicing in the same way and become approximants in intervocalic position. However, voiced labials behave somewhat differently when compared to other places and weaken the least.

However, my findings suggest that there is smaller difference between voiced and voiceless stops in velars as compared to alveolars. This was reported only in RI, but place of articulation was not statistically important in %V. The box plot in Figure 6 shows that voiced velars have slightly lower intensity than the other places, which indicates that, unlike what was shown in the studies mentioned above and what was predicted, voiced velar /g/ lenited less than the other two places. The most likely explanation for this could be what was mentioned in previous chapters. As it was mentioned in §3, marking the precise onset and offset of the voiced stops that have lenited is difficult due to the similarity of the voiced stops in the spectrogram to the surrounding vowels. In some cases where the formants were still visible and the intensity did not dip relative to the surrounding vowels,

I decided that complete deletion had happened (Colantoni & Marinescu, 2010) and I did not include those cases in this study. Among those cases, there was only 1 token with /g/ which was deleted due to extreme lenition. This cannot account for the reason why voiced velars did not show higher degree of lenition as compared to other places of articulation. However, the overall number of tokens with /g/ might have played a role in why the phonological expectation did not happen. Looking at Table 4 in §3, it is found that there are fewer voiced velars than voiced alveolars or labials. Therefore, a different result could come out if the number of tokens are even in future studies.

Another factor that should be taken into consideration is the effect of preceding contexts on /g/. Cole et al. (1999) found that /g/ weakens more when surrounding by /o,u/. They suggested that this effect is a consequence of the dynamics of the tongue body movement which is necessary to produce a consonant closing gesture. In the movement between /g/ and the adjacent vowel, when the change in the tongue body position is not required, /g/ is produced with a weaker realization. On the hand, in the cases where the tongue body position is changed in the movement between /g/ and an adjacent vowel, /g/ is fully realized. Looking at the current data, there are only four /g/ with preceding /o,u/. If this theory is true, this might be another reason for less weakening in voiced velars than other places of articulation. However, the effects of the surrounding vowels have not been always consistent in the previous literature. For instance, Colantoni & Marinescu (2010) found that /g/ lenites the least amount when surrounding by back vowels which contradicts what Cole et al. (1999) have stated.

Another contributing factor in Spanish lenition which might affect the weakening of /d/ is words ending with past participle suffixes such as *-ado*, *-ada*, *-ados*, *-adas*.

Eddington (2011) found /d/ is more lenited when it appears in these suffixes which are high frequency in Spanish. Eighty-three of the voiced alveolars in the current data were taken from word ending in *-ada*, and in 26 of these cases, /d/ was completely weakened to the point of elision. Considering the total number of 29 deleted /d/ in the data, this finding aligns with what Eddington (2011) suggested about high frequency suffixes. The tokens with *-ada* were not tested separately, however, the overall results show that alveolars and labials did not behave differently in terms of lenition.

5.2.2 Sociolinguistics and dialectology

Previous work shows that sociolinguistic factors such as age and dialect, among others, might affect the extent of weakening (Butera, 2018; Rogers & Mirisis, 2018). For example, Rogers & Mirisis (2018) found that younger speakers in Chile lenite /ptk/ to greater extent than the older age groups. Specifically, 18-24-year-old speakers showed higher level of voicing and articulatory reduction of the voiceless stops than 25-44- and 45-49-year-old speakers. They also thought that this attitude could persist, and the younger age group could continue to look at it as a marker of generational identity. The current study did not test for participant age to determine if this sociolinguistic factor affects the degree of consonant weakening in stop consonants in Argentine Spanish. As the data in my study come from a bigger database, it was not possible to control for participant age as well. To include bigger age range, I would collect my own data to have a better controlled study but due to the COVID 19 restrictions, that was not possible at the time. As a result of using the database, I ended up having a smaller age range from 34 to 57. For future studies, a bigger age range as well as more speakers should be considered for Argentine Spanish.

As discussed earlier, another factor that affects lenition is dialects. Previous work shows that certain varieties are at a more advanced stage of weakening of /bdg/ than others (Carrasco et al., 2012; Lewis 2001). As there are different varieties of Spanish spoken, it is important to investigate the process of lenition in all the dialects to have a clear understanding of consonant lenition. Therefore, my study will expand our knowledge about stop consonant lenition and voicing contrast in this particular variety of Spanish in a way that has not been looked before. However, all the speakers in my study were not from the same region in Argentina. As I did not look at each variety separately, future studies could explore specific regions more carefully.

Chapter 6: Conclusion

To sum up, the lenition of Spanish voiced stops has been considered extensively in the literature, but very few studies have looked at the lenition of voiceless stops and even much less is known about how the voicing contrast is maintained. Unlike previous research on consonant lenition, my study compares both stop series within the same study. My findings suggest that in Argentine Spanish, the stop voicing contrast is maintained and it does not depend on place of articulation. In contrast to other varieties where the voiceless stop weakens extensively, in Argentine Spanish the contrast is kept constant and there is very little overlap between voiced and voiceless stops. As I mentioned in the previous sections, I chose a corpus for my data from the *Linguistics Atlas of Argentina* (Colantoni, L., & Steele, J. (2004) *The University of Toronto Romance Phonetics Database* <http://rpd.chass.utoronto.ca/>). Due to the COVID-19 pandemic, in person data collection was not possible and it was difficult to collect data remotely. Since the data from *Linguistics Atlas of Argentina* were initially collected for another study, the number of tokens analyzed in the current study is not well-balanced in terms of voicing and place of articulation. Moreover, the tokens considered for this study were all in intervocalic position. As a result, the lenited tokens were not compared to non-lenited ones in other positions in the word. A better controlled study as well as analyzing other dialects should be considered for future research. Also, future work should determine how listeners perceive the acoustic measurements of contrast and find out if the acoustic cues found in production align with those used in perception.

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