

## Lenition of syllable-initial /p t k/ in a variety of Andalusian Spanish: Effects of linguistic factors and speech rate

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### ABSTRACT

This article examines the lenition patterns of syllable-initial /p t k/ in a variety of Andalusian Spanish. Twelve speakers from the same town completed a semi-directed interview from which a total of 2,400 instances of /p t k/ were extracted and analyzed. Three acoustic correlates were taken from each token: closure duration, intensity measurements, and voicing. The results indicate that more than half of the tokens were produced with, at least, partial voicing. The results also suggest that /p t k/ lenition occurs across word boundaries and is strongly conditioned by phonetic context, speech rate, and lexical stress. This study has significant implications for the study of sound change and language variation which are discussed in this article.

## 1. Introduction

This study examines the lenition patterns of syllable-initial voiceless stops (i.e., /p t k/) in a variety of Andalusian Spanish. The term Andalusian Spanish is often used to refer to the different varieties of Spanish spoken in the Autonomous Community of Andalusia, located in the south of the Iberian Peninsula. Although it is often regarded as one dialect of Spanish, Andalusian Spanish is far from being a homogeneous variety. In fact, a great deal of variation within Andalusia has been documented in previous studies, especially between Eastern and Western Andalusia (e.g., Villena-Ponsoda, 2008). Nevertheless, despite significant internal variation, the varieties of Spanish spoken in Andalusia are often considered to be innovative or non-standard (e.g., Hernández-Campoy, 2011, pp. 708-719), partially because lenition and overall phonological reduction is more widespread in Andalusian varieties than in other northern varieties. Some examples of phonological reduction that have been

widely documented in Andalusian Spanish include the phonological merger of /s/ and /θ/, the deaffrication of /tʃ/, glottalization or aspiration of /x/, elision of intervocalic /d/, or aspiration and deletion of /s/ in coda position (cf. Hernández-Campoy & Villena-Ponsoda, 2009 for a detailed overview). Despite the prevalence of lenition processes in Andalusian Spanish, and even though /p t k/ lenition has been widely documented in other varieties of Spanish (Broś & Lipowska, 2019; Hualde, Simonet & Nadeu, 2011; Lewis, 2001; Machuca Ayuso, 1997; Martínez Celdrán, 2009; Oftedal, 1985; O'Neill, 2010; Rogers & Mirisis, 2018; Ruiz-Hernández, 1984; Torreblanca, 1976; Torreira & Ernestus, 2011), our understanding of lenition of syllable-initial /p t k/ in Andalusian Spanish remains limited. This article aims to fill this gap in the literature by conducting an acoustic examination of /p t k/ among speakers of the same Andalusian town, and by examining different factors that contribute to the lenition of these sounds in this variety.

## 2. Background

Lenition of /p t k/ is a phenomenon that has been documented in multiple Romance languages such as Corsican (Gurevich, 2004), Sardinian (Jones, 1997), French (Torreira & Ernestus, 2011), Italian (Dalcher, 2008; Hualde & Nadeu, 2011), and Spanish (Broś & Lipowska, 2019; Hualde et al., 2011; Lewis, 2001; Machuca Ayuso, 1997; Martínez Celdrán, 2009; Oftedal, 1985; O'Neill, 2010; Rogers & Mirisis, 2018; Ruiz-Hernández, 1984; Torreblanca, 1976; Torreira & Ernestus, 2011). In the case of Spanish, this is not a new phenomenon. In fact, a lenition process affecting /p t k/ took place in the early development of Spanish from Latin (Penny, 2002). Just like modern Spanish, Latin had a phonemic contrast between voiced and voiceless stops (i.e., /b d g/ and /p t k/ respectively). However, unlike Spanish, Latin also had voiceless geminate stops (i.e., /pp tt kk/) in intervocalic position. As described by Martínez Celdrán (2002), these intervocalic geminates were linked to two syllable nodes (p. 37). However, in the early evolution of Spanish, these geminates became simple voiceless stops (e.g., Lat. SICCU > Sp. seco 'dry') due to a readjustment of the syllable structure in vulgar Latin by which intervocalic geminates lost their link to the first syllable node. This change had a significant phonological impact on the evolution of Spanish from Latin because Latin already had simple voiceless stops, and the reduction of geminates caused two different phonological categories to overlap phonetically. Nevertheless, there was an additional phonological change that would keep the contrast that existed originally between intervocalic geminates and simple voiceless stops: pre-existing intervocalic /p t k/ became /b d g/ (e.g., Lat. SECURU > Sp. seguro 'sure'). Likewise, pre-existing voiced stops became fricatives and even completely elided in modern Spanish (e.g., Lat. LĒGĀLE > Sp. leal 'loyal') (Penny, 2002). This series of chained events led to the current phonological system of Spanish that is often described as having two groups of phonemic stops: the phonemic voiced stops /b d g/, and the phonemic voiceless stops /p t k/. On the one hand, syllable-initial /b d g/ are often described as having two allophones in complementary

distribution: the voiced stops [b d g] and the voiced approximants [β ð ɣ]. On the other hand, the phonetic implementation of /p t k/ in onset position is often described as unaspirated voiceless stops (i.e., [p t k]).

Somewhat similar to the historical phonological change described above, a second round of voicing and lenition of /p t k/ has been documented in multiple varieties of modern Spanish (Broś & Lipowska, 2019; Hualde et al., 2011; Lewis, 2001; Machuca Ayuso, 1997; Martínez Celdrán, 2009; Rogers & Mirisis, 2018; Ruiz-Hernández, 1984; Torreblanca, 1976; Torreira & Ernestus, 2011).

Torreblanca (1976) constitutes one of the early studies that used spectrographic analysis to examine /p t k/ lenition in modern Spanish. The author examined the speech of speakers from 28 different towns in Toledo (central Spain), and while most of the tokens analyzed were produced prototypically (i.e., with a voiceless closure followed by a visible burst and a short-lag VOT), careful spectrographic examination also revealed the presence of voicing and spirantization. The author found more lenition in unstressed syllables, in function words, and among younger speakers.

More recently, researchers have conducted additional detailed acoustic analyses examining /p t k/ lenition in multiple varieties of Spain (Broś & Lipowska, 2019; Hualde et al., 2011; Lewis, 2001; Martínez Celdrán, 2009; O'Neill, 2010; Torreira & Ernestus, 2011) and Latin America (Lewis, 2001; Rogers & Mirisis, 2018). These studies and their main findings are discussed below.

Lewis (2001) examined the production of /p t k/ among four speakers from northern Spain and four speakers from central Colombia in three conditions: spontaneous speech, reading a written passage, and reading a list of words. The author considered five acoustic correlates in his analysis of /p t k/: 1) closure duration, 2) VOT, 3) percentage of voicing, 4) intensity difference between the lowest intensity value within the stop and the highest intensity value in flanking vowels, and 5) presence or absence of

release bursts. Four independent variables were included: speech style, place of articulation, lexical stress, and position in the word. An analysis of 864 tokens (36 tokens × 3 conditions × 8 participants) revealed that, while more lenition was found among speakers from northern Spain, the independent variables that favor /p t k/ lenition were similar in both varieties. In particular, more lenition was found in unstressed syllables and in more spontaneous tasks. A similar effect of style was reported by Hualde et al. (2011) in their analysis of the Spanish spoken in Majorca: 22% of /p t k/ tokens in their spontaneous corpus were fully voiced, compared to the 3.6% of fully voiced tokens in their read speech corpus.

Significant rates of /p t k/ voicing have also been documented in the Canary Islands. Broś & Lipowska (2019), for instance, conducted an examination of the linguistic and extralinguistic factors that condition Spanish non-continuant voicing among 20 speakers from Gran Canaria. Participants were asked to listen to a number of sentences and then repeat out loud the sentence they had heard. Their results revealed that 30% of the analyzed tokens were fully voiced, and approximately 15% of them showed partial voicing. Their results also suggest that men lenite more than women, that /k/ favors lenition, and that the presence or absence of phonetic voicing in the input had no effect on output pronunciations.

Regarding Latin American varieties, Rogers and Miris (2018) examined the linguistic and social factors that condition /p t k/ lenition among 32 participants from Concepción (Chile). For a total of 4,419 instances of /p t k/ from sociolinguistic interviews, the authors measured three acoustic correlates: 1) amount of voicing, 2) intensity difference between the stop consonant and the following vowel, and 3) closure duration. Their results suggest high rates of lenition in this variety: 54% of the /p t k/ tokens were fully voiced, and 4% were completely elided. The authors found that stress, place of articulation, as well as the sex and age of the speaker (younger males) favored this type of phonological reduction in this variety.

Differences in /p t k/ production are found not only across different varieties of Spanish (Lewis, 2001) but also across Romance languages (Torreira & Ernestus, 2011). Torreira and Ernestus (2011) examined and compared the production of /p t k/ in the Spanish spoken in Madrid and the French spoken in central and northern France. For a total of 1,298 tokens of Spanish /p t k/ and 856 tokens of French /p t k/, the authors examined the following acoustic correlates: 1) stop closure, 2) voicing duration; and 3) intensity velocity maxima during the consonant-to-vowel (CV) transition (i.e., intensity-based measurement that reflects the abruptness of the CV transition). Their results suggest that approximant-like realizations of /p t k/ are more frequent in Spanish than in French. Incomplete closures were more frequent and shorter for /k/ than for /p/ or /t/. Spanish has less abrupt transitions and shorter stop closures than French. A significant effect of stress was found (shorter closures in unstressed syllables). More voicing was found in Spanish than in French (e.g., 32.7% of the Spanish tokens were fully voiced as opposed to 8.5% in French, and 61.8% of the Spanish tokens were voiced for at least half of the total duration of the closure).

As can be noted from the discussion thus far, /p t k/ lenition varies significantly across varieties of Spanish and Romance languages. Although multiple researchers have examined different lenition processes in the speech of Andalusian speakers (e.g., Hernández-Campoy & Villena-Ponsoda, 2009), little is known about the extent to which /p t k/ are voiced and lenited in this variety. O'Neill (2010) does mention voicing and lenition of /p t k/ in Andalusia. After carrying out a spectrographic inspection of 167 tokens of /p t k/, O'Neill (2010) found that 115 were phonetically produced as voiced stops, and 31 were produced as voiced approximants. The author even mentions that /p t k/ and /b d g/ may be neutralized in this variety. While these findings are very revealing and suggest that /p t k/ lenition is highly frequent in Andalusian Spanish, our understanding of Andalusian /p t k/ lenition remains limited. For instance, O'Neill (2010) classified the different productions of /p t k/ based on visual examination of waveforms and

spectrograms, although no specific acoustic measurements were reported in his study. The current investigation will address this by examining quantitatively the acoustic properties of /p t k/ among speakers of Andalusian Spanish and analyzing the factors that contribute to such lenition.

In summary, we know from previous studies that Andalusian Spanish is a collection of varieties characterized by high rates of lenition of different consonantal sounds to such an extent that it is often regarded as an innovative or non-standard variety of Spanish (Hernández-Campoy & Villena-Ponsoda, 2009). However, our understanding of /p t k/ lenition in Andalusian varieties is limited. A systematic investigation of /p t k/ lenition in a variety of Andalusian Spanish represents an important contribution due to the implications that this linguistic phenomenon raises regarding sound change, as exemplified by the historical evolution of Spanish from Latin discussed earlier (Penny, 2002). This study aims to provide such a systematic analysis of /p t k/ in a sub-variety of Andalusian Spanish in order to shed light on the extent to which this phenomenon characterizes this variety, and the factors that contribute to it.

### 3. Research questions

Following the previous literature discussed above, this study addresses the following research questions:

- a) To what extent are /p t k/ lenited in the target Andalusian variety?
- b) What are the linguistic factors that contribute to such lenition?

Based on the discussion provided thus far, relatively high rates of lenition are expected in this variety. Specifically, it is expected that instances of /p t k/ in intervocalic position will share some of the acoustic properties that are often associated with /b d g/ (e.g., phonetic voicing, short duration, or higher intensity). Additionally, based on the results reported in previous studies, the factors that are expected to contribute to this type of variation include: place of

articulation, stress, phonetic context, type of word, and speech rate. Specifically, more lenition is expected in velars (Hualde et al., 2011; Lewis, 2001; Torreira & Ernestus, 2011), in unstressed syllables (Lewis, 2001; Torreira & Ernestus, 2011), and in function words (Torreblanca, 1976). Finally, since previous studies found more lenition in informal styles (Lewis, 2001; Torreblanca, 1976), a semi-informal interview will be used as the elicitation task, and speech rate will be included as an independent variable in the analysis. More information about the task and the different variables included in this study is provided in the following section.

## 4. Methods

### 4.1. Tasks

Since the goal of this study is to examine the production of /p t k/ in spontaneous speech, the elicitation task consisted of individual semi-directed interviews. Specifically, a photo-elicitation technique was used (Harper, 2002). Rather than just asking participants to describe pictures, this technique consists of using images as a source to generate discussion. Specifically, for a total of ten images, participants were shown one image or picture at a time, they were asked to briefly comment on the picture, and then the interviewer followed up with additional questions related to the picture. The pictures depicted various topics relevant to the participants, such as their hometown, people celebrating traditional holidays, and pictures related to current affairs and traveling, among others. Interviews varied in length, but they lasted approximately 30 minutes on average. Interviews were conducted in a quiet room, using a Shure WH20XLR head-mounted microphone, and an audio interface (BEHRINGER UMC22) connected to a laptop (MacBook Pro).

In addition to the interview, all participants also completed a background questionnaire that asked them to answer several questions about their age, gender, place of birth, native language, and highest level of education completed. The information

collected from this questionnaire is described in the following section.

## 4.2. Participants

A total of 12 speakers participated in the study. Three were men and nine were women. At the time of the study, their ages ranged from 21 to 52 (mean = 36; SD = 11.62). All of them had completed high school, two of them had also completed post-secondary professional training, and four of them had completed a university degree. All of them indicated Spanish as their native language, and all were originally from the same town in Eastern Andalusia: Martos (province of Jaén).

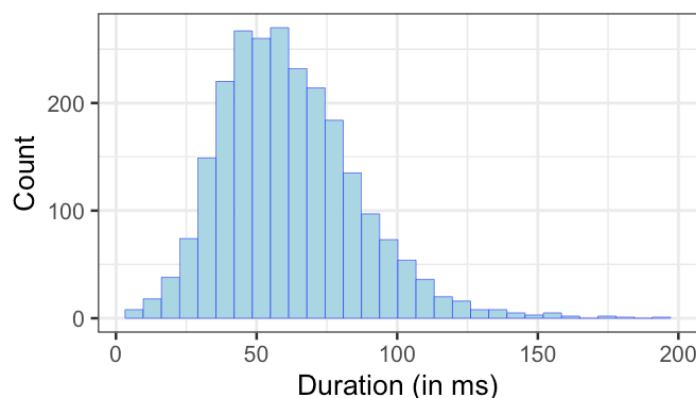
## 4.3. Data and acoustic correlates

For the purposes of this analysis, the first 200 productions of syllable-initial /p t k/ were extracted

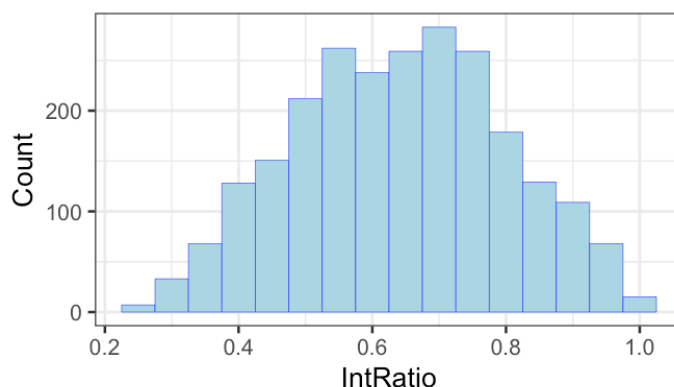
from each individual interview. Therefore, a total of 2,400 tokens were analyzed for the current study (12 participants  $\times$  200 tokens).

Each token was segmented and analyzed in *Praat* (Boersma & Weenink, 2021). The acoustic correlates that were measured for each token included: 1) closure duration, 2) intensity ratio (IntRatio), and 3) Voicing. These three acoustic correlates are described in more detail below.

First, closure duration was measured in milliseconds and corresponds to the time elapsed between the beginning of the segment to the consonant release. Therefore, duration is a continuous variable (min. = 9, max. = 193, mean = 82, SD = 29) and its distribution is illustrated in Figure 1.



**Figure 1.** Closure duration: distribution of the data.



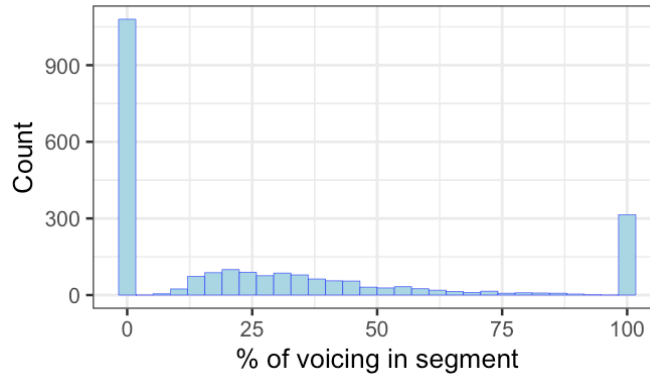
**Figure 2.** IntRatio: distribution of the data.

Second, in order to account for the gradient nature of lenition (e.g., File-Muriel & Brown, 2011; Martínez Celdrán, 2013; Melero-García, 2021), the degree of occlusion was determined by calculating the IntRatio of each production of /p t k/, rather than by classifying each instance of /p t k/ according to a finite set of categories (e.g., stop-like, approximant-like, etc.). Based solely on acoustic data, such a binary or categorical classification would have been, to some extent, arbitrary. Instead, the measurement

considered here (i.e., IntRatio) is a gradual one that was calculated by dividing the minimum intensity value within the stop closure by the maximum intensity value within the following vowel. This formula yielded a numeric value that ranged from zero to one (min. = 0.25, max. = 1, mean = 0.64, SD = 0.16). More lenited variants have values closer to one, whereas more occluded variants have IntRatio values closer to zero. The distribution of the IntRatio data is illustrated in Figure 2.

Finally, voicing was initially measured as the percentage of the segment that exhibited phonetic voicing, as reflected on the periodicity of the waveform and voicing bar in the spectrogram. As illustrated in Figure 3, some tokens were fully

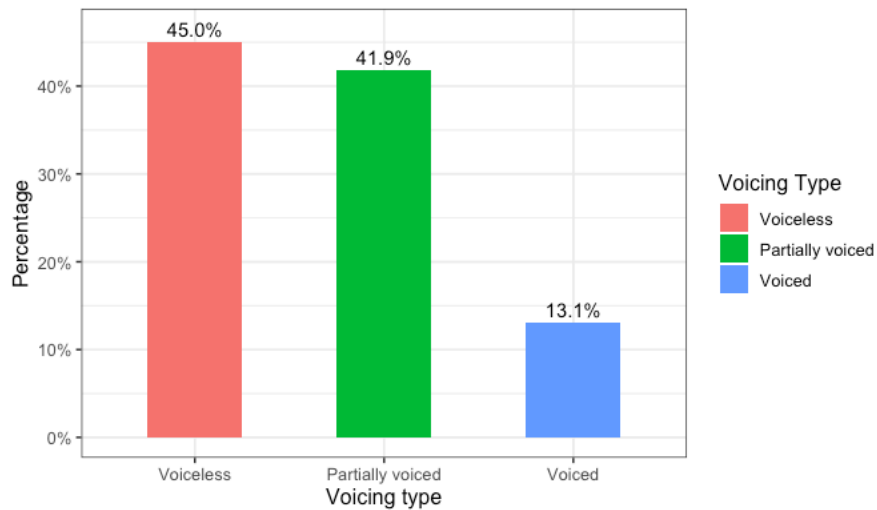
voiceless (i.e., 0% of voicing), others were fully voiced (i.e., 100%), and others fell somewhere in between.



**Figure 3.** Voicing: distribution of the data.

Given the distribution of these data, this variable was recoded as an ordinal variable with three levels (i.e.,

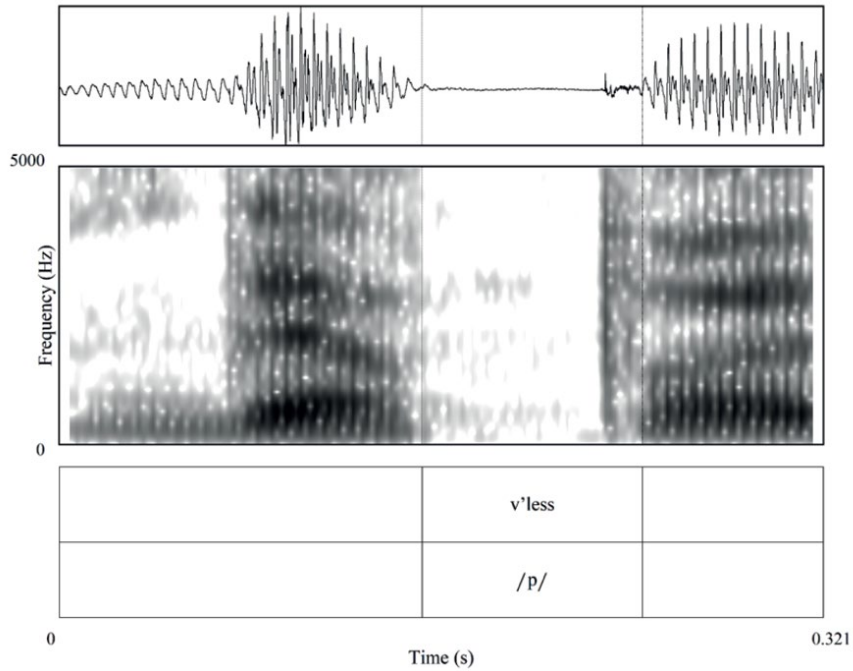
voiceless < partially voiced < voiced), as illustrated in Figure 4.



**Figure 4.** Voicing as an ordinal variable (voiceless < partially voiced < voiced).

Finally, Figures 5, 6, and 7 illustrate the waveforms and spectrograms of voiceless, partially voiced, and fully voiced tokens respectively. All these examples

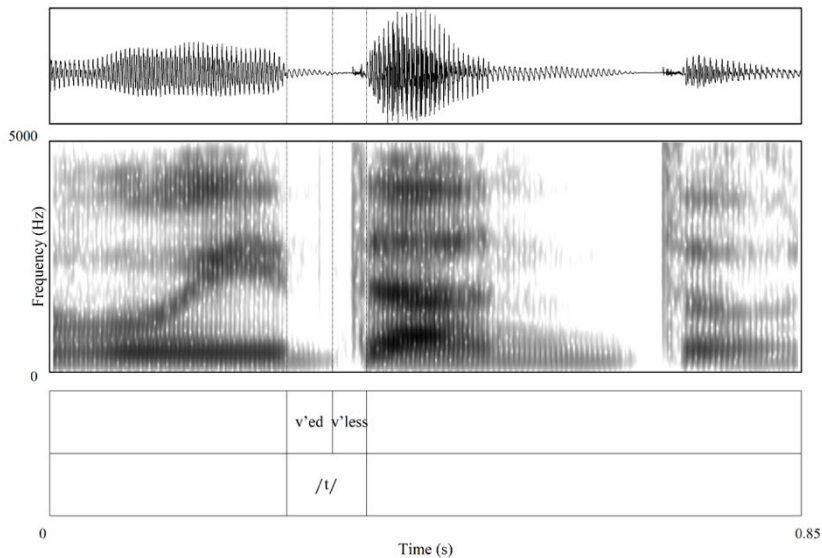
were extracted from the semi-directed interviews described above.



**Figure 5.** Voiceless /p/ in *después* ('afterwards').

Figure 5 shows the waveform and spectrogram for the word *después* ('afterwards'). The lack of

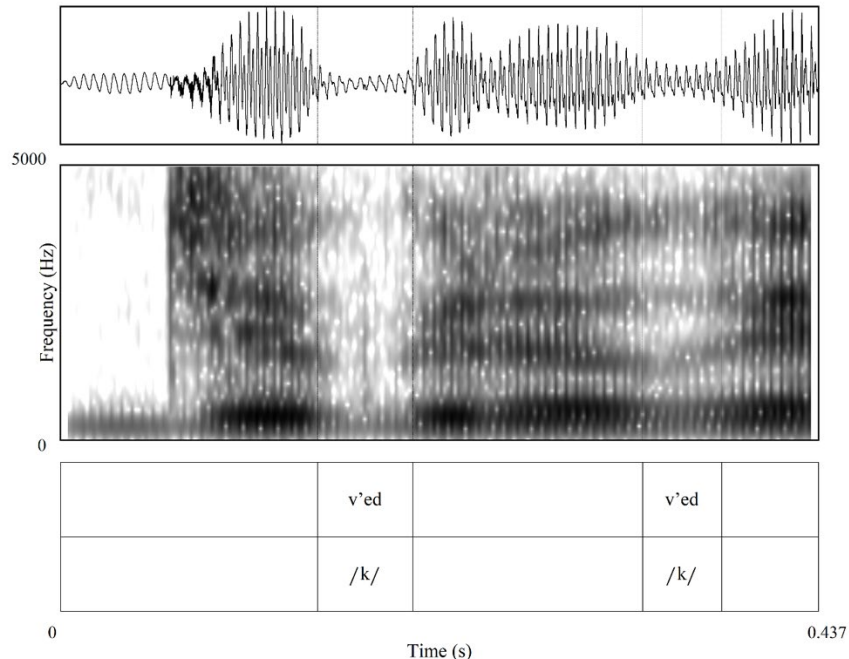
periodicity in the waveform as well as the lack of glottal pulses reveal that this /p/ was fully voiceless.



**Figure 6.** Partially voiced /t/ in *voy tanto* ('I go that often').

Figure 6 shows the waveform and spectrogram for the sequence *voy tanto* ('I go that often'). This token was produced as a partially voiced token, as it shows phonetic voicing on the left edge of the segment as evidenced by the periodicity in the waveform and the

presence of a voicing bar in the spectrogram. However, this voicing does not extend throughout the entire segment, as the right edge of the segment is phonetically voiceless.



**Figure 7.** Two phonetically voiced /k/ in the sequence *yo creo que* ('I think that').

Figure 7 shows the waveform and spectrogram for the sequence *yo creo que* ('I think that'), which has two fully voiced tokens of /k/. Both instances of /k/ in this example have a periodic waveform throughout the entire segment and a voicing bar is also visible in the spectrogram.

While different acoustic correlates were measured (closure duration, IntRatio, and voicing), all three of them are indicative of lenition or consonant reduction. For instance, Recasens (2002) defines lenition as changes that result from a reduction of both duration and degree of constriction, as well as changes in glottal activity that yield voicing. Therefore, for the purposes of this study, it will be considered that more lenited variants of /p t k/ are those with shorter closure durations, higher IntRatio, and more phonetic voicing.

#### 4.4. Independent factors

In addition to the aforementioned acoustic correlates, each token was coded for five linguistic independent variables: place of articulation, position within the word, phonetic context, lexical stress, and type of word.

Place of articulation is a categorical variable with three levels: bilabial /p/, dental /t/, or velar /k/.

Position of the stop consonant within the word is a categorical variable with two levels: word-initial or word-medial.

Phonetic context is also a categorical variable with two levels: post-vocalic and post-consonantal. As a reminder, all the instances of /p t k/ analyzed in this study are stops in syllable-initial position. It was considered that /p t k/ were post-vocalic when they were preceded by /i e a o u/. Likewise, it was considered that they were in post-consonantal position when they were preceded by /d l m n r s θ/.

As for lexical stress, this was also a categorical variable with two levels, and it refers to whether the stop was in a stressed or in an unstressed syllable.

Finally, type of word refers to whether the word where the stop appeared was a content word or a function word. Pronouns, prepositions, conjunctions, determiners, intensifiers, and interrogatives were coded as function words,



whereas nouns, verbs, adjectives, and adverbs were coded as content words.

In addition to these linguistic independent variables, each token was also coded for local speech rate, which was calculated by measuring the duration of a string of three words for each token: the word that contained /p t k/, the previous word, and the following word. The duration of this three-word string was divided by the number of phonological segments contained within the string. This yielded a numerical value that reflects the number of segments per second that were being produced by the speaker. Therefore, higher values indicate that the speaker was talking faster, whereas lower values indicate that speech rate was slower.

#### 4.5. Analysis

The data was subjected to three statistical analyses (one for each acoustic correlate: closure duration, IntRatio, and voicing). Regarding closure duration and IntRatio, since these two are continuous variables, mixed-effects linear regressions were run using the *lmerTest* package (Kuznetsova, Brockhoff & Christensen, 2017) in *R* (R Core Team, 2020). Regarding voicing, since this is an ordinal variable, a mixed-effects ordinal regression was run using the *ordinal* package (Christensen, 2019) in *R*. All three regressions included six independent variables (i.e., place of articulation, position in the word, phonetic context, stress, type of word, and local speech rate) as well as two random effects (word and participant). This information is summarized in Table 1.

Acoustic correlate	Type of regression	Independent variables	Random effects
Closure duration	Mixed-effects linear	Place of articulation Position in the word Phonetic context Stress Type of word Local speech rate	Word Participant
IntRatio	Mixed-effects linear		
Voicing	Mixed-effects ordinal		

**Table 1.** Summary of statistical analyses.

## 5. Results

### 5.1. Closure duration

The mixed-effects linear regression conducted with closure duration as the dependent variable revealed

significant effects of five independent variables: place of articulation, position within the word, phonetic context, stress, type of word, and speech rate. The results of the statistical analysis are presented in Table 2.

Variable	Reference level	Comparison	Estimate	SE	<i>t</i> -value	<i>p</i> -value
Place of articulation	/k/	/p/	15.610	1.342	11.634	< 0.001
	/k/	/t/	12.834	1.253	10.235	< 0.001
	/p/	/t/	-2.776	1.353	-2.052	< 0.05
Position	Word-initial	Word-medial	3.177	1.102	2.882	< 0.01
Phon. Context	Post-cons.	Post-vocalic	-2.746	0.975	-2.819	< 0.01
Stress	Unstressed	Stressed	7.359	1.056	6.971	< 0.001
Type of word	Content	Function	-1.559	2.085	-0.748	n.s. <sup>a</sup>
Speech rate			-2.231	0.108	-20.691	< 0.001

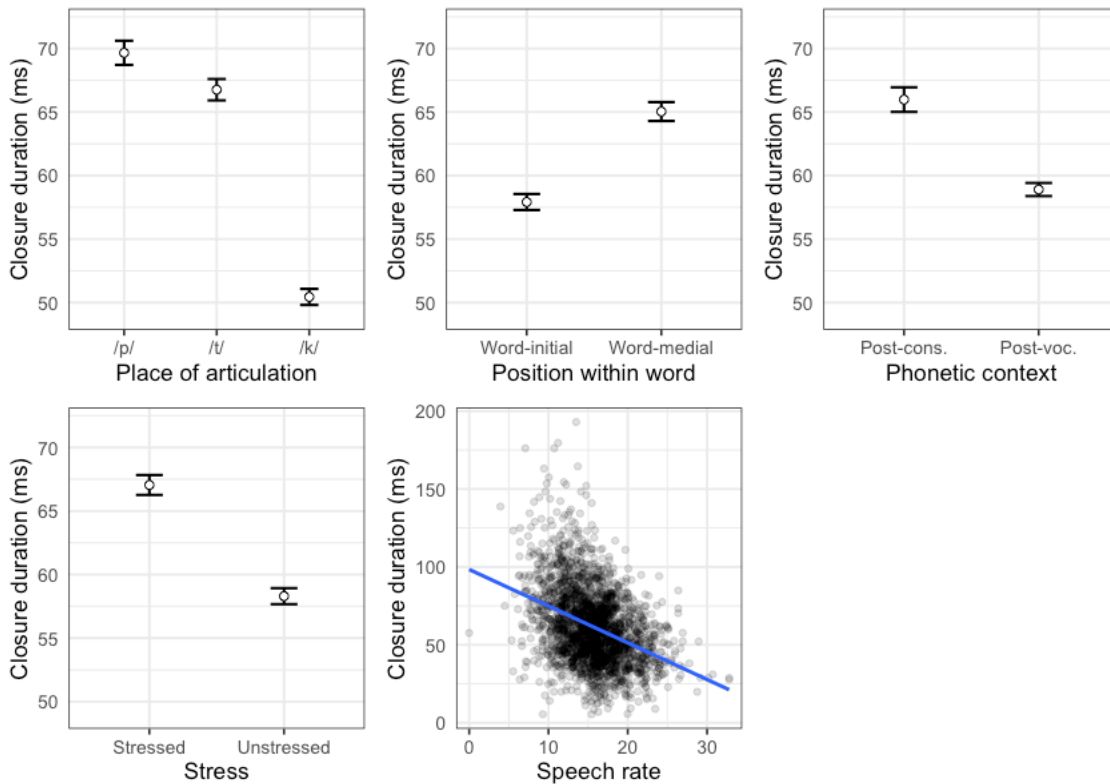
<sup>a</sup>n.s. = not significant (i.e., *p*-value > 0.05)

**Table 2.** Results from the mixed-effects linear regression with closure duration as response.

The different independent variables included in the analysis are listed on the left column of Table 2. The main goal of this analysis is to examine what levels of each independent variable favor more lenited realizations of /p t k/. For instance, the variable *place of articulation* has three levels (i.e., /p/, /t/, and /k/), and what we want to examine is whether there are significant differences between these levels in terms of closure duration. In order to make these comparisons explicit, the second and third columns of Table 2 indicate the levels that are being compared. The fourth column indicates the estimate for each comparison, that is, the deflections of each group relative to the reference level. For categorical variables, a positive estimate indicates longer duration as compared to the reference level, whereas a negative estimate indicates shorter closure duration as compared to the reference level. For instance, in the comparison of /k/ and /p/, the positive estimate

of 15.610 indicates that the closure duration of /p/ is longer than the closure duration of /k/, which is the reference level of that comparison. In other words, that estimate indicates that bilabials tend to have longer closures than velars. In the case of continuous variables, such as speech rate, a negative estimate indicates that as speech rate increases, closure duration decreases. Finally, the fifth, sixth and seventh columns include the standard error, t-value, and p-value for each comparison.

In order to provide a more visual representation of the data, the variables that yielded significant effects in the regression analysis are also illustrated in Figure 8. Specifically, for categorical variables, the mean and standard error of each level within each variable are illustrated. For speech rate, which is a continuous variable, a scatterplot with its linear trend is provided.



**Figure 8.** Relationship between closure duration and five independent variables (place of articulation, position within the word, phonetic context, stress, and speech rate).

Overall, the results presented in Table 2 and Figure 8 suggest a significant effect of the following

independent variables: place of articulation, position within the word, phonetic context, stress, and speech

rate. Specifically, velars are the place of articulation with the shortest closures, followed by dentals, and then bilabials (i.e., /k/ < /t/ < /p/). Additionally, stops in unstressed syllables have shorter durations than those in stressed syllables. Likewise, stops in post-vocalic position have shorter closures than those in post-consonantal position. Interestingly, word-initial stops are slightly shorter than word-medial stops. A significant effect of speech rate was also found according to which stops have shorter closures when

speakers are speaking faster. Finally, no significant effect of type of word was found in the analysis of closure duration.

### 5.2. IntRatio

The mixed-effects linear regression conducted with IntRatio as the dependent variable revealed significant effects of five independent variables, as summarized in Table 3 and illustrated in Figure 9.

Variable	Reference level	Comparison	Estimate	SE	t-value	p-value
Place of articulation	/k/	/p/	-0.053	0.008	-6.378	< 0.001
	/k/	/t/	-0.049	0.008	-6.371	< 0.001
	/p/	/t/	0.004	0.008	0.494	n.s. <sup>a</sup>
Position	Word-initial	Word-medial	-0.013	0.007	-1.824	n.s. <sup>a</sup>
Phon. Context	Post-cons.	Post-vocalic	0.069	0.006	11.089	< 0.001
Stress	Unstressed	Stressed	-0.061	0.007	-9.241	< 0.001
Type of word	Content	Function	0.037	0.012	3.090	< 0.01
Speech rate			0.014	0.001	19.091	< 0.001

<sup>a</sup>n.s. = not significant (i.e., p-value > 0.05)

Table 3. Results from the mixed-effects linear regression with IntRatio as response.

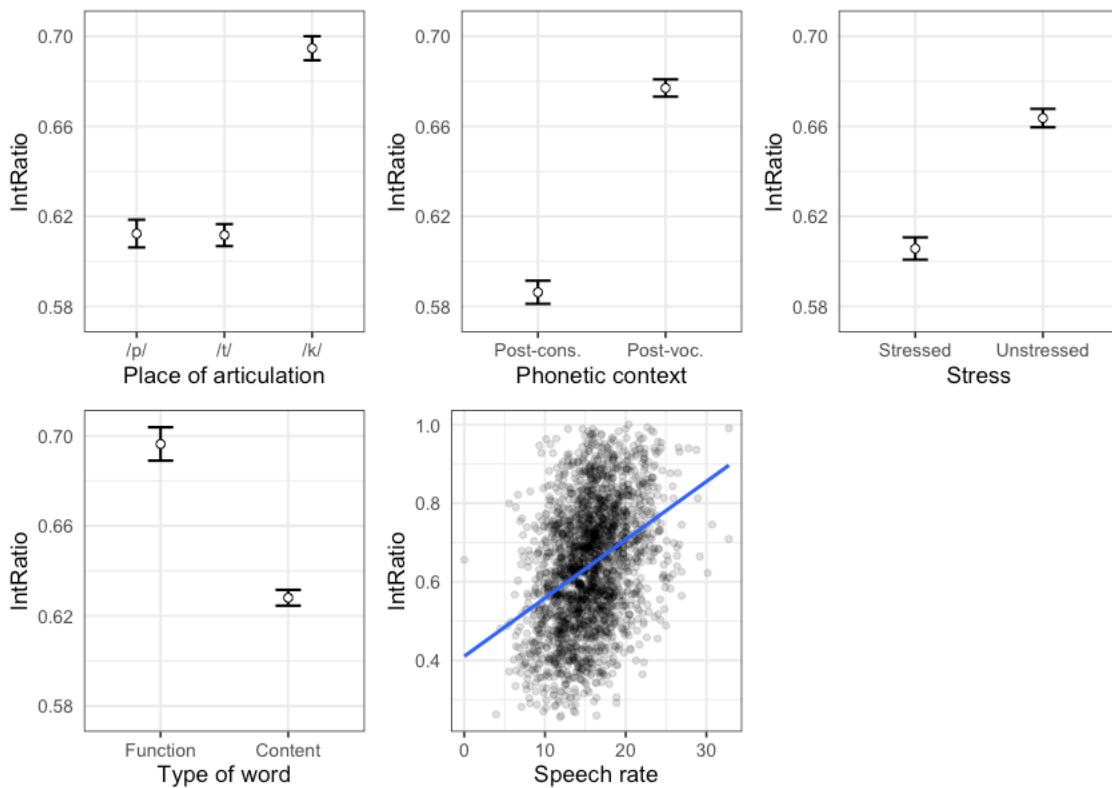


Figure 9. Relationship between IntRatio and five independent variables (place of articulation, phonetic context, stress, type of word, and speech rate).

The results presented in Table 3 and illustrated in Figure 9 indicate that velars are less constricted (i.e., they have higher IntRatio) than bilabials and dentals. No significant difference was found between bilabials and dentals. Stops are also less constricted in post-vocalic position, in unstressed syllables, in function words, and at higher speech rates. No significant effect of word position was found regarding IntRatio.

### 5.3. Voicing

The mixed-effects ordinal regression conducted with voicing as the dependent variable revealed significant effects of five independent variables: place of articulation, phonetic context, stress, and type of word. The results of the statistical analysis are presented in Table 4 and the significant variables are also illustrated in Figure 10.

Variable	Reference level	Comparison	Estimate	SE	<i>t</i> -value	<i>p</i> -value
Place of articulation	/k/	/p/	0.435	0.152	2.868	< 0.01
	/k/	/t/	0.132	0.141	0.934	n.s. <sup>a</sup>
	/p/	/t/	-0.303	0.151	-2.009	< 0.05
Position	Word-initial	Word-medial	-0.054	0.126	-0.426	n.s. <sup>a</sup>
Phon. Context	Post-cons.	Post-vocalic	3.297	0.143	23.093	< 0.001
Stress	Unstressed	Stressed	-0.405	0.123	-3.288	< 0.01
Type of word	Content	Function	0.626	0.205	3.048	< 0.01
Speech rate			0.097	0.013	7.267	< 0.001

<sup>a</sup>n.s. = not significant (i.e., *p*-value > 0.05)

**Table 4.** Results from the mixed-effects ordinal regression with voicing as response.

Ordinal logistic regression calculates cumulative probabilities assuming the hierarchical order of the dependent variable (voiceless < partially voiced < voiced). In this case, and similar to the results presented for closure duration and IntRatio earlier, a positive estimate indicates increased odds of being in a higher category (whether moving from voiceless to partially voiced, or from partially voiced to voiced). For instance, the positive estimate 3.297 for phonetic context indicates that stops in post-vocalic position are more likely to be produced with more voicing than those in post-consonantal position. Likewise, a negative estimate indicates increased odds of being in a lower category (i.e., less voicing). In order to facilitate the interpretation of these results, the variables that yielded significant effects in the regression are illustrated in Figure 10.

Overall, these results suggest that, when considering both partial and full phonetic voicing, bilabials are the place of articulation that exhibits more voicing. However, it is also important to note that velars constitute the place of articulation with the highest number of tokens that were fully voiced.

Additionally, a significant difference was found with respect to phonetic context: most tokens that were either partially or fully voiced were in post-vocalic position. Very few instances of post-consonantal /p t k/ were produced with phonetic voicing. A significant effect was also found regarding type of word: stop consonants that appear in content words (e.g., verbs, nouns, etc.) tend to be produced with less voicing than those in function words (e.g., conjunctions, prepositions, etc.). A small difference was also found regarding stress: more voicing was found in unstressed syllables than in stressed ones. Finally, the effect of speech rate suggests that the presence of voicing increases as speech rate increases.

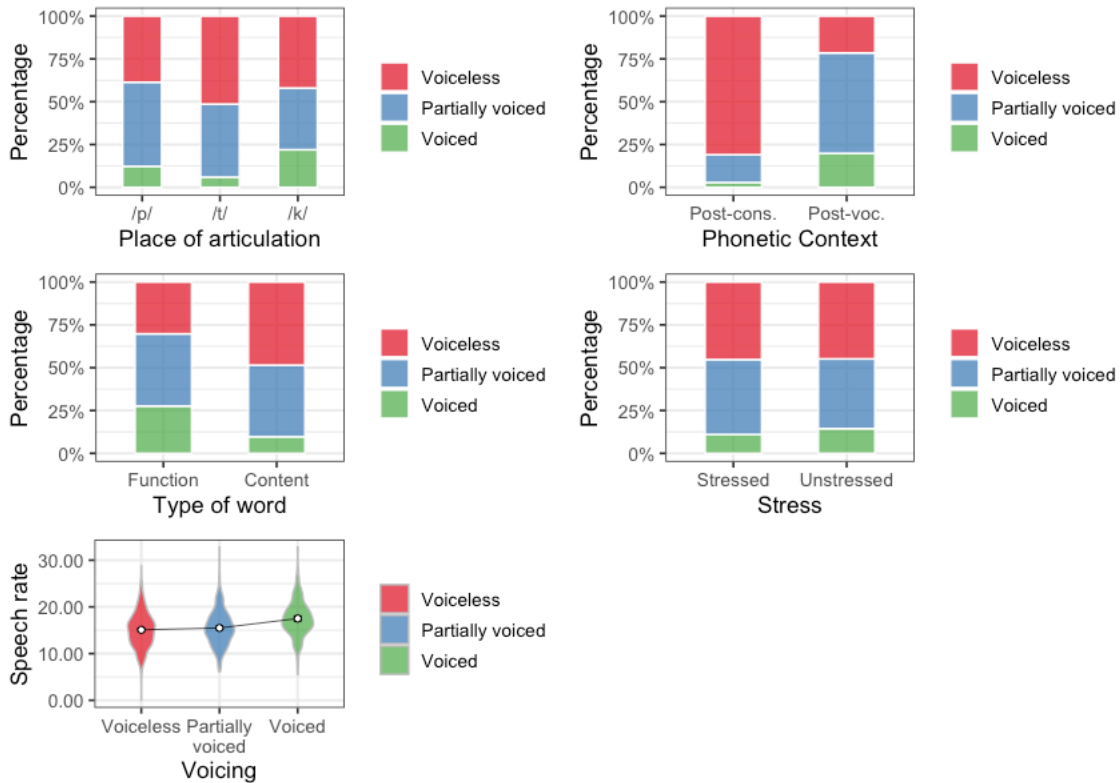
The results presented in this section and their implications are further discussed in the following section.

### 6. Discussion

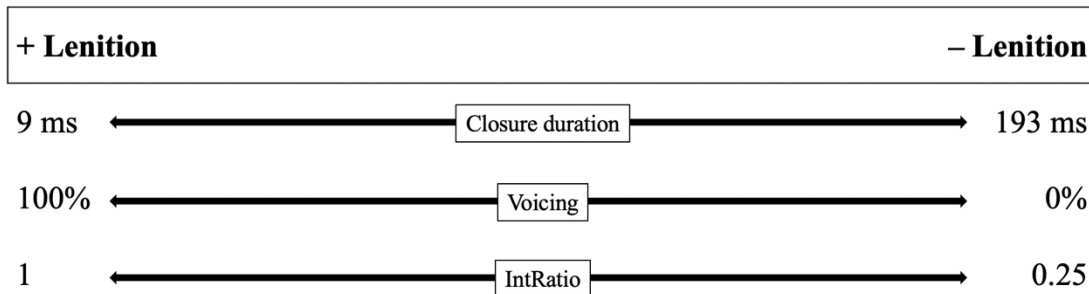
The goal of this study was to examine the lenition process that affects /p t k/ in a sub-variety of eastern

Andalusian Spanish, as well as how different linguistic factors and speech rate contribute to such lenition. Our operationalization of lenition was based on Recasens' (2002) definition according to which lenition refers to consonantal weakening that results from a reduction of duration and degree of constriction, as well as an increase in glottal activity or voicing. Based on this definition of lenition, three

acoustic measurements were considered: closure duration, IntRatio, and degree of voicing. As illustrated in Figure 11, more lenited instances of /p t k/ are those with shorter closure duration, more voicing, and higher IntRatio. This operationalization is also consistent with findings reported in previous studies of /p t k/ lenition (Machuca Ayuso, 1997).



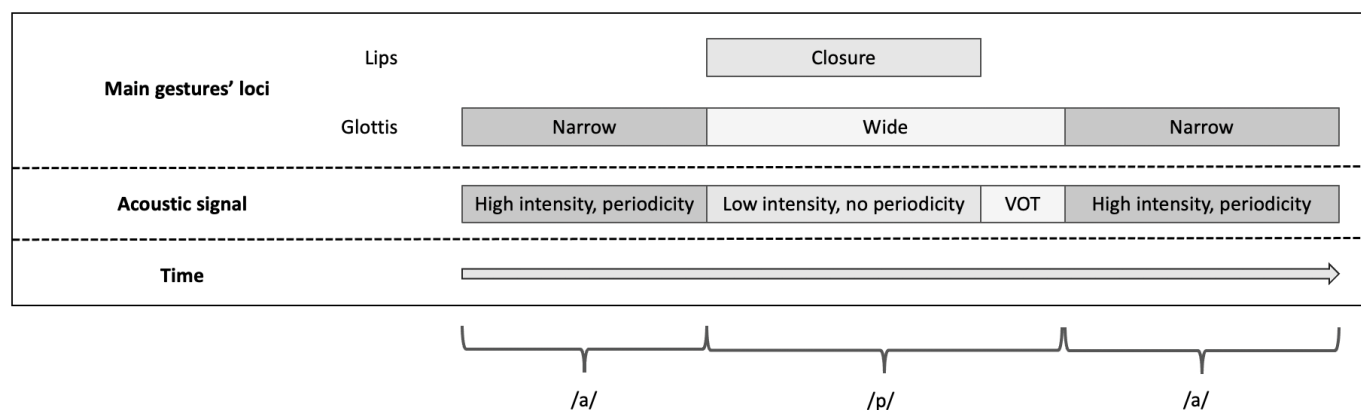
**Figure 10.** Relationship between voicing and five independent variables (place of articulation, phonetic context, type of word, stress, and speech rate).



**Figure 11.** Operationalization of lenition based on closure duration, voicing, and IntRatio.

The results of three statistical analyses revealed significant effects of phonetic context, lexical stress, and speech rate for the three acoustic correlates that were considered. Specifically, more lenited variants of /p t k/ were found in post-vocalic position, in unstressed syllables, and when speakers were talking faster. These effects have phonological implications and can be better understood when considering the gestural organization in the production of these sounds. Specifically, in articulatory phonology

(Browman & Goldstein, 1989, 1992) speech is analyzed in terms of articulatory gestures, which are coordinated along a spatial and a temporal dimension. This means that articulatory gestures can create different degrees of constriction at different locations in the vocal tract, and they are articulated in a specific chronological order. Figure 12 illustrates the main gestures involved in the production of post-vocalic /p/ in the sequence /apa/ along a spatial and a temporal dimension.

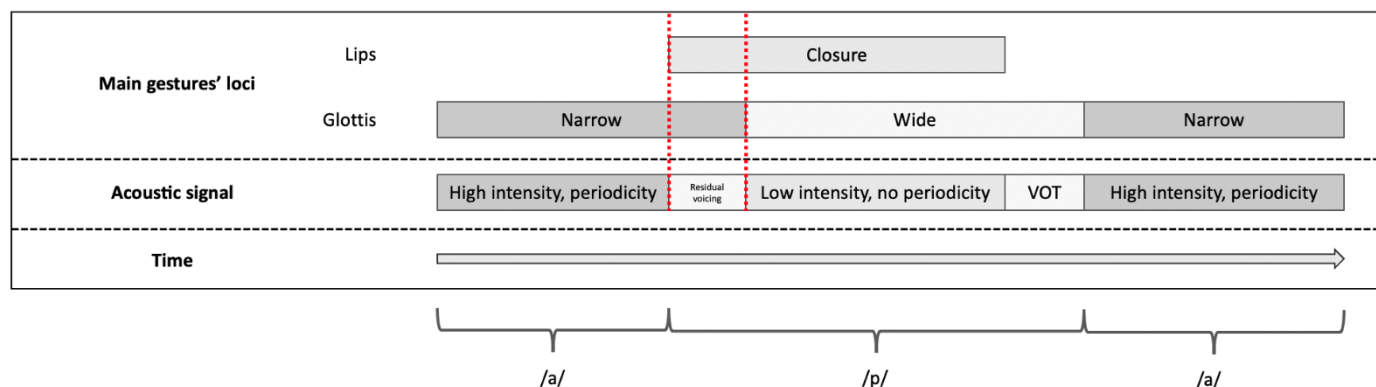


**Figure 12.** Gestural organization and acoustic correlates of prototypical post-vocalic /p/.

As schematized on Figure 12 above, in the production of post-vocalic voiceless stops, two main gestures are involved during the vowel-to-consonant transition. The first one is the oral constriction, which in the case of bilabials takes place in the lips. This means that the upper and lower lips come together and create a full closure. The second one is the abduction of the vocal folds. During the production of a vowel, the vocal folds are usually adducted or close together (i.e., narrow glottis), which allows them to vibrate. However, during the production of Spanish voiceless stops, the vocal folds abduct or come apart (i.e., wide glottis), thus stopping vocal fold vibration. The two gestures (i.e., oral constriction and the abduction of the vocal folds) are synchronized in such a way that both are expected to take place at relatively the same time. When this happens, the result is a fully voiceless stop. As previously discussed, this was the case for 45% of the tokens analyzed in this study (see Figure 4 above).

Nevertheless, it is not uncommon for these gestures to overlap, especially in spontaneous speech as well as in prosodically less prominent positions, such as in unstressed syllables. Such gestural overlap is illustrated in Figure 13.

As illustrated in Figure 13, in running speech, the glottal abduction and the oral constriction often become misaligned. In particular, if the oral constriction takes place before the vocal folds abduct completely, the result is a partially voiced stop with phonetic voicing on the left edge of the segment. This is a frequent phenomenon in the variety analyzed in this study given that 41.9% of the analyzed tokens were partially voiced, all of which had phonetic voicing on the left edge of the segment as illustrated on the waveform and spectrogram of Figure 6 above. It is also possible for the voicing caused by this type of gestural overlap to extend throughout the entire segment, yielding fully voiced tokens. In fact, 13.1% of the /p t k/ tokens analyzed in this study were completely voiced from a phonetic point of view.



**Figure 13.** Gestural overlap and acoustic correlates of a partially voiced /p/.

This articulatory description helps us understand the significance of factors such as phonetic context, stress, and speech rate given that the phonetic voicing of /p t k/ is primarily the result of coarticulation between the stop consonant and the previous vowel. Additionally, gestures are more likely to become misaligned at higher speech rates, and phonological reduction is expected in contexts that are less prominent from a prosodic standpoint, such as in unstressed syllables.

In addition to phonetic context, speech rate, and stress, another variable that was significant in all three analyses was place of articulation. The analyses of closure duration and IntRatio suggest that velars are more lenited than bilabials and dentals. The analysis of voicing revealed that, while bilabials are the place of articulation that exhibits more partial voicing, it is velars the ones that exhibit uninterrupted voicing more frequently. Previous studies have also found that Spanish /k/ tends to have more incomplete closures (Torreira & Ernestus, 2011) and more voicing (Broś & Lipowska, 2019; Hualde et al., 2011) than /p/ and /t/. In fact, Recasens (2002) states that velars tend to undergo more lenition not only in Spanish, but in other Romance languages as well. This may be due to physiology: as Cho and Ladefoged (1999) point out, the movement of the lips or the tongue apex are usually faster than the movement of the tongue dorsum. Compared to the quick movement of the lips and the tongue apex in the production of /p/ and /t/ respectively, the slower movement of the tongue

dorsum in the production of /k/ means that it takes longer for the articulators to come together as well as to come apart. Therefore, when speech rate is high, the articulation of /k/ may be subject to more undershoot than /p/ and /t/, which then causes velars to exhibit more lenition.

In addition to the effects of place of articulation, phonetic context, stress, and speech rate, which were significant in all the analyses conducted in this study, the analyses of IntRatio and voicing also revealed a significant effect of type of word. Specifically, the results suggest that function words tend to be more lenited and have more voicing than content words. There are several possible explanations to these findings. From a prosodic point of view, function words tend to be less prominent than content words, which may make them more susceptible to lenition. Additionally, function words may be more frequent than content words, and previous research has suggested that high-frequency words undergo phonological reduction faster than low-frequency ones (Bybee, 1999, 2001, 2002). Therefore, it is possible that the significant effects found for type of word may be due to either prosodic or frequency effects. More research is needed to confirm these hypotheses.

Finally, an additional finding that is worth discussing is the effect of position within the word. This variable was not significant in the analysis of voicing or IntRatio. The only significant effect of word position was found in the analysis of closure

duration, which suggested that /p t k/ in word-initial position have shorter closures than those in word-medial position. Overall, these results suggest that /p t k/ lenition is a phenomenon that occurs across word boundaries in the variety of Spanish examined in this study. This finding is consistent with previous studies of modern Spanish and is particularly interesting since it has significant implications for our understanding of sound change. Interestingly, from a diachronic perspective, the type of lenition and voicing process that led to phonological recategorization of stops in the evolution of Spanish from Latin affected consonants in word-medial position but not in word-initial position (e.g., Lat. *SAPĒRE* > Sp. *saber* ‘to know’ vs. Lat. *ILLA PORTA* > Sp. *la puerta* ‘the door’). The fact that the current investigation as well as previous studies on other varieties of Spanish and other Romance languages (Hualde, 2013; Hualde & Nadeu, 2011; Hualde et al., 2011; Torreira & Ernestus, 2011) have found that lenition of /p t k/ occurs across word boundaries may seem contradictory. However, authors like Hualde (2013) and Hualde et al. (2011) have proposed a multi-stage model of sound change that can account for these findings. These authors argue that the initial stage of this type of sound change is characterized by some type of gestural reduction or overlap that causes a good deal of phonetic variation. For instance, during this initial stage of sound change, the sequence /apa/ may be realized phonetically as [aba], [aβa], [aφa], among other possible variants. At a later stage, one of those phonetic forms become conventionalized across word boundaries (e.g., /p/ is consistently realized as [b] in a specific context, such as in post-vocalic position). Then, at the final stage of the sound change, this phonetic conventionalization can lead to phonological recategorization (i.e., /p/ is interpreted as /b/). This phonological recategorization does not operate across word boundaries but rather on individual lexical items “in part due to memory failure” (Hualde, 2013, slide 39). This model of sound change can explain why the diachronic change described above affected stop consonants in word-medial position only, but /p t k/ lenition in modern Spanish occurs across word boundaries. Specifically, the examples of the evolution of

Spanish from Latin reflect the last stage of the sound change proposed by Hualde (2013) and Hualde et al. (2011), which involves phonological recategorization. Given that phonological recategorization may take place, in part, due to memory failure (Hualde, 2013), word-initial consonants are less likely to undergo phonological recategorization because they appear in a wider range of phonetic contexts (e.g., post-consonantal, post-vocalic) than consonants in word-medial position. This way, since word-initial stops often appear in contexts that do not favor lenition (e.g., post-consonantal), speakers are less likely to misinterpret /p t k/ as /b d g/ due to memory failure because when they appear in post-consonantal position they are likely to be produced as voiceless stops. However, post-vocalic word-medial stops always appear in a context that favors lenition, and are thus more likely to undergo phonological recategorization during this last stage of this model of sound change.

Nevertheless, this type of phonological recategorization is not what we see in modern Spanish, where /p t k/ lenition occurs across word boundaries and, as discussed earlier, is the result of gestural overlap and coarticulation, rather than recategorization or memory failure. Additionally, the results presented in this paper suggest that /p t k/ lenition is not a fully conventionalized phenomenon given that not all tokens of post-vocalic /p t k/ were fully voiced. Instead, a great deal of variation resulting from coarticulation and gestural overlap was found. Therefore, the fact that /p t k/ lenition in in this variety is a phenomenon that results from coarticulation and that affects these consonants across word boundaries, along with the fact that phonetic conventionalization was not observed (e.g., not all instances of post-vocalic /p t k/ were fully voiced) may be an indication that we may be before the initial stage of this type of sound change. As such, phonological recategorization of stops in the near future may be unlikely in this variety.



## 7. Conclusions and future directions

The goal of this paper was to examine the extent to which phonemic voiceless stops are lenited and voiced among speakers from an eastern Andalusian community, as well as to shed light on the linguistic factors that motivate such phonological process. To that end, a total of 2,400 instances of /p t k/ were acoustically analyzed. Specifically, three acoustic correlates were measured for each token: closure duration, IntRatio, and voicing. Closure duration, measured in milliseconds, refers to the time elapsed between the onset of the stop consonant and its release. IntRatio is an intensity-based measure that reflects the degree of occlusion of the stop consonant. It ranges from zero to one. Values closer to zero indicate that the consonant was more occluded than those with values closer to one. Finally, phonetic voicing was coded ordinally using three categories (i.e., voiceless < partially voiced < voiced). Closure duration, IntRatio, and voicing constitute the three dependent variables of the statistical analyses that were conducted. The independent variables were the same for the three analyses, and included the following: place of articulation, type of word, position within the word, phonetic context, lexical stress, and speech rate. The results suggest that there is a great deal of variation and that /p t k/ lenition is frequent in this variety of Spanish. In fact, of all tokens analyzed, only 45% were produced prototypically (i.e., fully voiceless). The rest of the tokens were either partially voiced (41.9%) or fully voiced (13.1%). The factors that contribute the most to this type of lenition were speech rate, phonetic context, lexical stress, and place of articulation. In fact, all of these factors were significant in all statistical analyses. Based on these results, it has been argued that this type of lenition results from the overlap and misalignment of the articulatory gestures involved in the production of these sounds. This type of phonetic variation has significant implications for sound change, as evidenced by the phonological changes that took place in the evolution of Spanish from Latin. Nevertheless, given that the type of lenition examined in this study takes place across word boundaries and the great amount of phonetic

variation observed in the data, it is concluded that phonological recategorization in the near future is unlikely in this variety of Spanish.

Even though Andalusian Spanish is often regarded as a collection of innovative, non-standard varieties of Spanish that are characterized by exhibiting high rates of lenition, our understanding of /p t k/ lenition in this region was limited. In this regard, this study provides a significant contribution as it provides a detailed examination that sheds light on the lenition patterns of /p t k/ in a community located in eastern Andalusia. Of course, as is the case with most scientific research, this study is not without limitations, and more research is needed in order to understand the full range of variation of Andalusian /p t k/. Specifically, it would be interesting to examine the extent to which social variables such as age, gender, or socioeconomic status may affect /p t k/ production, as this could be very informative regarding sound change in this variety. This would require a larger and more balanced pool of participants. Furthermore, additional studies of /p t k/ lenition in other parts of Andalusia are necessary, as we know from previous research that Andalusian Spanish is not a homogeneous variety, and significant internal geographical variation is common. All this is beyond the scope of the current investigation, but it is suggested as fruitful lines of research for future studies.

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