UNIVERSITAT ROVIRA I VIRGILI

SPANISH STOP LENITION AND THE TEMPORAL DIMENSION: AN ACOUSTIC APPROACH

Antonia Soler Cervera

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Spanish Stop Lenition and the Temporal Dimension: An Acoustic Approach

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Ph.D. Thesis

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I STATE that the present study, entitled "Spanish Stop Lenition and the Temporal Dimension: An Acoustic Approach", presented by Antonia Soler Cervera for the award of the degree of Doctor, has been carried out under my supervision at the Department of English and German Studies of this university.

Tarragona, February 21, 2024

Doctoral Thesis Supervisor

Dr. Joaquín Romero Gallego

Declaration

I, Antonia Soler Cervera, declare that this dissertation, carried out at Universitat Rovira i Virgili in partial fulfilment of the requirements for the degree of Doctor of Philosophy, is entirely my own work, and it has not been submitted in whole or in part for qualification at any other university.

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Abstract

This dissertation presents a study that investigates Spanish stop lenition as a gradual weakening phenomenon which is conditioned by multiple factors. Voiced stop weakening in Spanish has been depicted as a context-dependent process by which /b, d, g/ are spirantized to [β, ð, ɣ] in all contexts except in initial position, after nasals and, exceptionally after /l/ for homorganic /d/. The nature of this phenomenon has been discussed from different perspectives, both phonetically and phonologically. Phonetically, the emphasis has been placed on the description of lenited realizations and their features, mainly based on information provided by acoustic data. These analyses have revealed some variability in the resulting realizations of lenition processes, with a range of closure degrees. From a phonological point of view, stop lenition has traditionally been described as a categorical process, but the variability observed has motivated further phonological interpretations. The effect of stress, and contextual factors on stop lenition realizations has been tested in a number of studies, but other factors have been posited to play a role in the phenomenon, such as speaking rate.

This study hypothesizes that the temporal dimension has a fundamental role in the Spanish stop lenition process, where the target realization is not completely achieved due to timing constraints. Contextual factors are also hypothesized to exhibit different patterning across speaking rates. In order to test these hypotheses, a laboratory experiment was designed including a range of contexts and two speaking rates as independent variables. An acoustic analysis procedure was used that can avoid segmentation inconsistencies in acoustic cue measurements. The results show that speaking rate has a major effect in the spirantized realization, as the corresponding acoustic cues analysed for constriction degree are significantly different across rates. Contextual effects are also conditioned by time, which triggers a range of constriction degrees for context-rate interactions. These results can be best interpreted from an Articulatory Phonology perspective, which provides a framework to explain how time and constriction degree go along in Spanish stop lenition.

Resum

Aquesta tesi presenta un estudi que investiga l'afebliment de les consonants oclusives sonores en espanyol com un procés gradual i condicionat per múltiples factors. Aquest fenomen es presenta com un procés pel qual /b, d, g/ esdevenen [β, ð, ɣ] en tots els contextos excepte en posició inicial, després de nasal i, excepcionalment després de /l/ per la consonant homorgànica /d/. La naturalesa d'aquest fenomen ha estat analitzada des de diferents perspectives, tant fonèticament com fonològicament. La fonètica ha posat l'èmfasi en la descripció de les realitzacions resultants i les seves característiques, principalment a partir de dades acústiques. Aquestes anàlisis han revelat certa variabilitat en les realitzacions resultants dels processos de lenició, amb diferents graus de constricció. Tradicionalment, la fonologia ha descrit el fenomen com un procés categòric, però la variabilitat observada ha motivat altres interpretacions fonològiques. L'efecte de l'accentuació i els factors contextuals en les realitzacions de les oclusives sonores han estat objecte d'estudi, però s'ha plantejat que altres condicionants, com ara la velocitat de parla, poden tenir un efecte en la variabilitat en l'afebliment de les consonants.

Aquest estudi planteja la hipòtesi que la dimensió temporal té un paper fonamental en el procés de lenició de les consonants oclusives en espanyol, on la constricció de l'oclusiva no és completa degut a una limitació temporal. També es planteja la hipòtesi que els factors contextuals presenten diferents patrons segons la velocitat de la parla. Per tal de provar aquestes hipòtesis, es va dissenyar un experiment de laboratori que inclou una sèrie de contextos i dues velocitats de parla com a variables independents. Es va utilitzar un procediment d'anàlisi acústica per minimitzar inconsistències en la segmentació a l'hora de mesurar els corresponents paràmetres acústics. Els resultats mostren que la velocitat de parla té un efecte important en la realització de les consonants oclusives afeblides, ja que els paràmetres acústics associats al grau de constricció són significativament diferents per les dues velocitats. Els efectes contextuals també estan condicionats per la dimensió temporal, ja que la velocitat de parla determina diferents graus de constricció en la interacció amb diferents contextos. Aquests resultats es poden interpretar des de la Fonologia Articulatòria, que proporciona un marc que pot explicar com la dimensió temporal i els graus de constricció interactuen en el procés d'afebliment de les oclusives sonores de l'espanyol.

Resumen

Esta tesis doctoral investiga el debilitamiento de las consonantes oclusivas sonoras en español como un proceso gradual condicionado por múltiples factores. Este fenómeno se presenta como un proceso por el cual /b, d, g/ surgen como [β, ð, ɣ] en todos los contextos excepto en la posición inicial, después de nasal y, excepcionalmente después de /l/ para /d/. La naturaleza de este fenómeno ha sido analizada desde diferentes perspectivas. La fonética ha puesto el énfasis en la descripción de las realizaciones resultantes, principalmente a partir de la información proporcionada por datos acústicos. Estos análisis han revelado cierta variabilidad en los procesos de lenición, con distintos grados de constricción. Tradicionalmente, la fonología ha descrito el fenómeno como un proceso categórico, pero la variabilidad observada ha motivado otras interpretaciones fonológicas. El efecto de la acentuación y los factores contextuales en las realizaciones de las oclusivas sonoras han sido objeto de estudio, pero se ha planteado que otros condicionantes, tales como la velocidad de habla, pueden tener un efecto en la variabilidad que se observa en la lenición de /b, d, g/.

Este estudio plantea que la dimensión temporal tiene un papel fundamental en el proceso de lenición de las consonantes oclusivas en español, donde la constricción de la oclusiva no es completa debido a una limitación temporal. También plantea que los factores contextuales presentan diferentes patrones según la velocidad del habla. Para probar estas hipótesis, se diseñó un experimento de laboratorio que incluye una serie de contextos y dos velocidades de habla como variables independientes. Se utilizó un procedimiento de análisis acústico para minimizar inconsistencias en la segmentación y en la medición de los parámetros acústicos correspondientes. Los resultados muestran que la velocidad de habla tiene un efecto importante en la realización de las consonantes oclusivas debilitadas, puesto que los parámetros acústicos asociados al grado de constricción son significativamente diferentes para ambas velocidades. Los efectos contextuales también están condicionados por la dimensión temporal, ya que la velocidad de habla determina distintos grados de constricción en la interacción con distintos contextos. Estos resultados se pueden interpretar desde la Fonología Articulatoria, que proporciona un marco adecuado para explicar cómo la dimensión temporal y los grados de constricción interactúan en el proceso de debilitamiento de las oclusivas sonoras del español.

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Chapter 1 Introduction

Stop lenition has become one of the most frequently-discussed phenomena in Spanish phonetics and phonology. Being a common process across all varieties of the language, Spanish stop lenition has been described, more traditionally, as an instance of consonant lenition or weakening whereby the voiced stops /b, d, g/ surface as continuants in all contexts except in initial position, after nasals, and exceptionally after /l/ in the case of /d/ (Harris, 1969; Martínez-Celdrán, 1984, 1991b). However, some studies have also provided evidence of variability in the outcome of the phenomenon, resulting in a number of attempts to look into the nature of Spanish stop lenition and the factors that can account for the variability of /b/, /d/ and /g/ realizations (see for example, Cole et al, 1999; Hualde, Shosted & Scarpace, 2011; Martínez-Celdrán, 2008; Ortega-Llebaria, 2004; Romero, 1994; Simonet et al., 2012, or Soler & Romero, 1999).

In order to investigate the phenomenon, several approaches have been proposed, seeking to describe the phonetic features of the spirantized realizations and to categorize the process as a phonological event. While the experimental evidence provided in different studies seems to agree with respect to the phonetic description of lenited realizations (Colantoni & Marinescu, 2010; Martínez Celdrán, 1991; Romero, 1995; Simonet et al., 2012; Soler & Romero, 1999), disagreement arises with respect to the description of the nature of the phenomenon and its phonological categorization (Colina, 2020; González, 2006, Hualde, 1989; Kirchner, 2004; Kingston, 2008; Martínez-Celdrán, 2008).

Although there is some consensus concerning the phonetic features of spirantized voiced stops and the variability in their realizations, a more controversial issue is the role that different factors play in the Spanish stop lenition processes, which has motivated a number of studies. The observed influence of contextual conditions on the lenited realizations has encouraged research on the specific effects of flanking vowels and consonants on the spirantized /b/, /d/ and /g/ (Cole et al, 1999; Romero, 1994; Hualde et al, 2010). Similarly, specific studies have focused on how stress conditions lenition processes and how the position of voiced plosives with respect to prosodic constituents also affects the spirantized realization (Cole et al, 1999; Lavoie, 2001; Ortega-Llebaria, 2004; Kingston, 2008). Further, other factors have also been posited to play a role in the phenomenon, such as speaking style and speaking rate (Romero & Soler, 2019, Soler & Romero, 1999, Soler & Romero, 2013).

In order to look into different issues in the research carried out on Spanish stop lenition, the present chapter first states the purpose of this dissertation in Section 1.1. Then, it delves into some central theoretical issues concerning coarticulation and consonant weakening in Section 1.2. Section 1.3 looks into the nature of Spanish stop lenition as a multi-dimensional phonetic phenomenon, while Section 1.4 reviews different phonological views that have been proposed to provide an account of the phenomenon. Section 1.5 discusses some analysis methods employed in stop lenition studies. Finally, in Section 1.6 some hypothesized general assumptions about expected results in this dissertation are presented, together with their potential implications.

1.1 Objectives

While voiced stop lenition in Romance, and particularly in Spanish, has been a recurrently discussed process in the literature, the different issues raised as to the nature of the phenomenon posit it as a multi-dimensional process which deserves further consideration. In the line of previous studies, the purpose of this study is to revise the nature of stop lenition in Spanish as a weakening phenomenon in the light of experimental data based on laboratory conditions. More specifically, the present work attempts to provide a picture of the process involved in Spanish stop lenition by investigating the role of the temporal dimension and contextual factors, and how the variability observed in the spirantized realizations is mainly conditioned by time (Soler & Romero, 1999, 2013), which is considered one of the motivating factors underlying voiced stop weakening. According to the reported findings, a general discussion on the processes involved in Spanish stop lenition is also presented in the light of Articulatory Phonology premises.

1.2 Coarticulation and lenition phenomena

In order to examine the processes involved in Spanish stop lenition, it is essential to point to certain notions commonly associated with the phenomenon, namely, coarticulation, gestural overlap and gestural blending and how they are also related to consonant weakening. Some traditional definitions of coarticulation focus on the phonetic nature of the phenomenon. Hammarberg (1976, p. 357) defines it as “a process whereby the properties of a segment are altered due to the influences exerted on it by neighbouring segments". Later on, Hammarberg (1982) revises this definition to include the importance of the notion of segment and the fact that segments are "perceptual-cognitive categories" that cannot be understood from "physicalistic" models only. This idea also preceded a great deal of discussion in phonetic and phonological approaches to coarticulation phenomena and coarticulation as language-dependent processes based on speakers' mental representations of segments, phonemes and coarticulation processes.

Other definitions found in the literature follow similar lines from a phonetic perspective, while other significant approaches are based on premises of phonological theory. For example, Kühnert & Nolan (1999, p. 7) affirm that "coarticulation refers to the fact that a phonological segment is not realized identically in all environments but often apparently varies to become more like an adjacent or nearby segment". Other widely accepted definitions of coarticulation are based on the premises of Articulatory Phonology (Browman & Goldstein, 1992), where articulatory gestures are considered the minimal phonological units and are defined according to specific articulatory tasks that are performed in the vocal tract. Thus, Ladefoged (2001, p. 247) defines coarticulation as "the overlapping of adjacent articulatory gestures". Fowler & Salzman (1993, p. 173) state that "coarticulation refers to the fact that at any given point during an utterance, the influences of gestures associated with several adjacent or near-adjacent segments can generally be observed in the acoustic or articulatory patterns of speech".

Also based on Articulatory Phonology, Recasens (1999, p. 81) defines coarticulation as a "temporal coproduction of gestures", whereby a distinction is made between *coarticulation proper* and *gestural overlap*. He states that coarticulation may involve independent articulators or specific tongue regions, and so effects are different according to those facts. *Coarticulation proper* refers to those cases where the articulatory structures are intrinsically connected (different parts of the tongue, for example), while *gestural overlap* refers to cases where independent articulators are involved. In any case, a coarticulation event requires contact between two or more sounds to influence each other. This influence may occur from left to right (*carryover* coarticulation), or from right to left (*anticipatory* coarticulation).

More recently, two studies by Recasens (2018, 2019) provide a state-of-the-art review of definitions and articulatory phenomena associated with coarticulation. He defines coarticulation as "the articulatory modification of a given speech sound arising from coproduction or overlap with neighbouring sounds in the speech chain"

(Recasens, 2018, p. 1), offering a broader view on coarticulation processes. He explains that several articulatory structures may be involved and coarticulation may result from the activation of a single articulatory gesture or from the interaction among articulatory gestures for different segments. He also describes how different articulatory structures play a role in coarticulation processes, such as the role of the velum in nasalization, or the behaviour of different tongue regions in VCV sequences. According to these studies, coarticulation involves gestural overlap, and may affect different articulatory structures and acoustic properties, such as segmental duration.

Recasens (2019) also suggests a clear distinction between coarticulation, assimilation, and gestural blending. He states that coarticulation and assimilation involve "intersegmental adaptation". Coarticulation effects may involve articulatory regions that are not directly involved in the production of a vowel or a consonant, such as the modification of lingual positions in the articulation of a consonant in contact with different vowels. Coarticulation may also modify slightly the place of articulation in CV sequences, or the manner or articulation in sequences where a nasal consonant is present. However, assimilation is different in that in involves complete modification of the place or manner of articulation, for example /n/ becoming /ŋ/ before /k/. In both coarticulation and assimilation (partial or complete), one segment (trigger) exercises an effect on another (target) in a given direction (anticipated or regressive). On the contrary, gestural blending is understood as affecting homorganic sequences mainly and both segments affect each other without a specific direction. In heterorganic sequences, blending may occur when constriction locations are close in space and time.

These studies also include some remarkable observations regarding coarticulation facts and the action of articulators. In Recasens (2018) it is suggested that CV sequences result in more extensive gestural overlap than consonant clusters, since they involve lower production constraints than CC sequences, while in CC clusters, more blending may be expected. In addition, coarticulatory patterns may also be determined by other conditions, such as speech rate, prosodic factors, segmental position, speaker, lexical frequency, and language. Among these, Recasens (2018), refers to how the temporal dimension may play an important role, for example, in the time that is necessary for a speaker to lower the velum for a nasal consonant in contact with an oral consonant, for lip-rounding anticipation or extension for the production of /u/ as a flanking segment, or the time required to activate voicing in the larynx. Regarding language-dependent features that may also have an effect on coarticulation processes, he refers to differences in the number or vowels or consonants in a given system, which may lead to specific adjustments and patterns. Previously, the author in Recasens et al. (1997) also delves into coarticulation processes by proposing a model of lingual coarticulation based on articulatory constraints (Degrees of Articulatory Constraints, or DAC). Using electropalatographic and acoustic data, this study analyses VCV sequences in Catalan, including two vowels and seven consonants to specify constriction degree data for lingual contact and the involvement of different tongue regions. Their findings suggest that the model accounts for constriction degrees satisfactorily, and shows that constriction degree depends on the primary articulator and manner of articulation, and these differences greatly condition the adaptation to one another in consonant clusters, including coarticulation directionality. Later, in similar lines, Recasens & Pallarès (2001) analyse gesture coordination mechanisms and phonological assimilatory processes in the light of the DAC model to predict coarticulation, assimilation and blending in consonant clusters in Catalan, showing that results for C-to-C effects largely agree with predictions.

Coarticulation, or gestural overlap, assimilation and gestural blending are related to weakening processes as the cause and/or the effect, and they are central to some studies on lenition. Romero (1996), for example, analyses different Spanish consonant clusters in the light of the gestural overlap involved and resulting assimilation processes. Electromagnetic articulometry data is used in this study to analyse different articulatory configurations and the action of articulators in the production of those clusters, including sequences where lenition occurs. His results show that, in Articulatory Phonology terms, tract variable assimilation processes affect constriction location and constriction degree together, and suggests that differences in tract variable specification for different languages are also expected to result in assimilation differences. More recently, Recasens & Mira (2015) also show that segmental weakening has an effect on assimilation processes in some word boundaries in Catalan consonant sequences involving nasals, laterals and plosives. They point out that weakening may be generally revealed as less lingual contact, shorter duration, less oral pressure, voicing extension, and articulatory undershoot, showing a relationship between assimilation and lenition processes.

For the purpose of the present work, it is assumed that coarticulation phenomena are involved in stop lenition processes and their effects are analysed to look into /b/, /d/ and /g/ lenition in the CV and CC sequences. However, the term *coarticulation* may be used more generally than defined by Recasens (2019) to refer to effects of articulatory configurations in the specific sequences analysed, since further investigation into those processes (coarticulation, assimilation and blending) as representing different types of articulatory events is not the aim of this work.

Just as coarticulation phenomena have been reported in the literature from different perspectives, consonant lenition processes have also been defined according to different phonetic and phonological grounds. Section 1.3 and 1.4 below focus on specific descriptions of Spanish stop lenition from different perspectives. However, more generally, some descriptions have tried to explain facts and features associated with the phenomenon. For example, Lass (1984) identifies a relationship between lenition and an increase in sonority and openness, where increased sonority is understood as increased output of periodic acoustic energy, and increased openness means decreased resistance to airflow. He proposes a scale of sonority and a scale of openness to define weakening degrees. Similarly, Trask (1996) defines lenition as a phonological process in which a segment becomes less occluded or more sonorous. Along these lines, Lavoie (2001) defines lenition as a process in consonant strength change where sonority is increased and the consonant becomes less consonantal as it assimilates to the vocalic environment. She also states that it represents a change towards deletion, from a diachronic perspective. Lavoie argues that sonority increase and marked structure (feature specification) decrease may provide appropriate grounds to identify alternations that could be classified as lenition processes, such as voicing, approximantization, fricativization, debuccalization, and deletion.

A particularly-relevant approach to a description of lenition is provided by Articulatory Phonology (Browman & Goldstein, 1989; 1992), a theory that defines lenition as a decrease in duration and magnitude of articulatory gestures resulting from articulatory undershoot. Previous studies on lenition processes have advocated for the premises involved in this approach (Parrell, 2011; Recasens, 2015, Romero, 1992, 1995, 1996), and the present work also relies on Articulatory Phonology to account for Spanish voiced stop lenition as described in more detail below and in Chapter 4.

1.3 The multi-dimensional nature of Spanish spirantization and its phonetic features

As mentioned previously, Spanish stop lenition has drawn the attention of numerous studies from different perspectives, which have provided a multi-faceted picture of the phenomenon. In this section, some of the previous accounts on Spanish stop lenition are discussed in order to provide a thorough description of the phenomenon. Among the first references to Spanish, we mainly find descriptions of the phonetic features of spirantized realizations. A well-known study by Navarro Tomás (1971), for example, although based on impressionistic views, already suggests differences between voiced stops and spirantized allophones. Even though he describes lenited realizations as fricatives, he describes shorter durations of spirantized consonants, duration variability and differences in constriction degree, when he refers to “la estrechez de su articulación” (Navarro-Tomás, 1971, p. 381).

This evidence is supported by later experimental studies that place emphasis on describing the phonetic features of approximant realizations as opposed to voiced plosives. Thus, Martínez Celdrán (1984, 1991b) focuses on the acoustic features of spirantized realizations and provides acoustic data that justifies a distinction between them and their corresponding obstruent counterparts, on the one hand, and fricatives on the other hand. He describes the prototypical acoustic features of spirant approximants, namely, low-frequency sonority (voice bar), striations that are typical of vowels corresponding to glottal pulses, and clear formant structures. In contrast, he describes voiced plosives as exhibiting a voice bar and an occlusion interval that ends with a release burst. Based on acoustic data, he advocates for the position of classifying these realizations as approximants, also referring to their shorter closure duration and their increased relative intensity as clear acoustic correlates.

Martínez-Celdrán (2008, 2013) provides further discussion on the features of voiced stop realizations and makes a clear distinction between approximants, fricatives and stops. He focuses on the occurrence of the categorized lenited realizations in identified positions. For that purpose, he refers to constriction degree issues (as presented in Catford, 1977) in the distinction between them. Finally, in Martínez-Celdrán (2013), the author aims to delve into the effect of flanking segments on the frequency of occurrence of approximant realizations, and he looks into the features of different realizations according to contextual factors. Some of his findings will be relevant to the present study in that flanking segments will also be taken into consideration.

Other relevant studies provide some insights into the factors that intervene in stop lenition processes: specific flanking segments, stress, position, or differences between /b/, /d/ and g/ in spirantized realizations. One of the factors that have been posited to have an effect is the position of the consonant with respect to word stress. Ortega-Llebaria (2004) compares the production of intervocalic /b/ and intervocalic /g/ in Spanish and English and the role of stress and vowel context in the degree of lenition. She finds that the degree of weakening in intervocalic /g/ varies according to stress, and she reports less lenited pronunciations in prosodically strong positions. However, by comparing the effects of phonetic factors across languages, she also shows that those effects may be limited by inventory constraints according to sound contrasts in the language. Similarly, Lavoie (2001) more generally concludes that duration, one of the main acoustic cues of consonant lenition, is significantly conditioned by stress.

Another conditioning factor that has been claimed to affect consonant lenition is the prosodic environment concerning the position in the word. Lavoie (2001) suggests a hierarchy of weak positions: word final-medial-initial position. While initial positions appear to yield clearly stronger realizations, in general, consonant lenition is affected by the position in the word to a lesser degree. As to onset and coda syllable positions, Escure (1977) claims that onsets constitute stronger positions than codas. This view seems to be supported by Martínez-Celdran & Regueira (2008) for Galician stop lenition, who suggest that codas favour more lenited realizations, but is in contrast to Romero & Honorof (2004), who report non-spirantized realizations. Eddington (2011) also looks into the effect of stress and word position, and he reports that /b/ and /d/ appear as less lenited than /g/ when followed by a stressed syllable, while the three of them are less lenited when they fall between two stressed syllables. Still other studies that are relevant to the present work investigate effects of lenition in voiceless stops and how it favours merger with the voiced counterparts in final positions (including Catalan and Basque). Other studies also focus on the features of lenited /p, t, k/ and how differences between these and /b, d, g/ are perceived by speakers. For some of these studies, see for example, Hualde, Simonet & Nadeu, 2011; Hualde & Zhang, 2022; Machuca, 1997; Parrell, 2011 and Romero et al., 2007.

An extensively discussed factor that conditions the variability of spirantized realizations in Spanish is the effect of flanking segments, although some disagreement can be observed in the light of the reported results. Romero (1994) provides both acoustic and articulatory evidence of contextual variation and reports a relationship between the outcome of voiced stop lenition and the constriction degree of the preceding consonant, especially exemplified by the flanking consonants /r/ and /s/. Similarly, Cole et al. (1999) report effects of vowel quality on spirantized /g/, with flanking /i/, /e/ and /a/ conditioning lesser degrees of lenition than /u/ or / o/. However, Kingston (2008) finds a significant effect of flanking consonants but no consistent effect of vowel openness. Likewise, Colantoni and Marinescu (2010) report no clear pattern for the effect of vowel-type on the duration of spirantized voiced stops in Argentine Spanish. Other studies on the role of contextual factors include Hualde, Shosted & Scarpace (2011), in which the realization of /d/ in different contexts is analysed. The articulatory data presented show that /d/ is most occluded after /n/ and /l/ and least occluded after a vowel or /r/, while /s/ triggers some intermediate occlusion. The acoustic results show that /d/ is especially constricted after /s/ while it is less constricted after /n/ or /l/.

Furthermore, although based on data for Catalan, another relevant study focusing on the effect of contextual factors is Recasens (2015). He analyses differences in stop lenition in heterosyllabic syllables in word boundary position. This study provides further evidence that voiced stop lenition is a variable process where resulting realizations depend on contextual features, including the consonant and the vowels involved. He finds that realizations are less lenited after fricatives than after sonorants, and more lenited in intervocalic positions. The study also looks into the degree of voicing associated to lenition, and finds that in analysing the effects of C1 on C2, more lenited realizations exhibit more voicing.

Besides stress, prosodic environment and flanking segments, other factors have been suggested to have an effect on Spanish stop lenition such as speaking rate and speaking style. Although both of them have been posited as additional conditions to the variability observed in spirantized realizations, there is no extensive evidence that accounts for how these factors play a role. For the purpose of this study, speaking rate is posited to have a crucial effect on the variability observed in spirantized consonants. Soler & Romero (1999, 2013) find evidence of effects of speaking rate on consonant durations and on intensity values. These studies show that slow speaking rates favour longer durations and more occluded realizations, providing some evidence on how speaking rate conditions the constriction degree of lenited voiced stops. The results also confirm that the effect of contextual factors is especially relevant in Spanish stop lenition and it is considered that the interaction between these two factors deserves special attention in order to provide a more complete picture of the process involved in such a common phenomenon. Similarly, Romero & Soler (2019) investigate Spanish heterorganic CC sequences, where both segments are voiced plosive consonants or where C1 is a voiced plosive and C2 is a nasal. These clusters have drawn much less attention in Spanish stop lenition research and the study looks into the presence or absence of lenition of C1 and how it conditions C2 constriction degree. Speaking rate is introduced to observe more lenited or more occluded realizations. The results show evidence that constriction degrees for C1 and C2 are more strongly related for the fast rate, favouring higher degrees of lenition. The study also concludes that the directionality of the condition (C1 affecting C2) deserves further observation.

As mentioned previously, voiced stop lenition also occurs across different varieties of Spanish and other Romance languages, which has encouraged the study of the phenomenon and its specific characteristics for different varieties. Stop lenition in Argentine Spanish has been studied in Colantoni & Marinescu (2010), where they investigate the degree of lenition in voiced and voiceless stops. They predict that there is some correlation between increased approximantization of voiced stops and voicing of voiceless stops. From an effort-based approach, they also predict that more effortful gestures (i.e. voiceless plosives) should lenite first, and open vowels should trigger higher rate of lenition. A third prediction, based on perception, states that (a) lenition may not be affected by the constriction degree of flanking vowels, and (b) voiced stops lenite the most. Their findings show that only the third prediction is partially confirmed, since lenition does not appear to be consistently driven by more open vowels, and voiced stop realizations show stronger lenition than voiceless plosives.

Other studies focus on comparing Spanish stop lenition effects in specific varieties of Spanish. For example, Costa Rican Spanish has been studied in Carrasco (2008) and Carrasco et al. (2012), where they compare the allophonic distribution of voiced stops in Costa Rican and Castilian Spanish (Madrid) in various phonetic contexts. Carrasco et al. (2012) analyse lenition outcomes by place of articulation, preceding segment, word-position (initial or medial), lexical stress, and speech style in postconsonantal (after a liquid, sibilant or glide) and postvocalic (after /a/) contexts. Their findings provide evidence of clear differences between postconsonantal and postvocalic realizations of /b/ and /d/ in Costa Rican Spanish, while in Castilian Spanish there is a continuum of constriction degrees, depending on the nature of the specific preceding segment. Furthermore, word-medial intervocalic position favours lenition in both varieties, but stop realizations are more frequent in Costa Rican Spanish in word-initial position. Other studies comparing Spanish stop lenition effects in different varieties of Spanish include specifically the effects of contextual factors. Arróniz &

Willis (2023) compare the effects of aspirated /s/ in /s/ + /b, d, g/ in Andalusian and Mexican Spanish, and discuss potential compensation strategies in the production of voiced plosives in Mexican Spanish sequences and the production of fricatives in Andalusian. They also investigate how these differences are perceived by speakers of both varieties.

Furthermore, stop lenition in Canary Islands Spanish is studied in Broś et al. (2021), who examine postvocalic lenition of voiceless and voiced stops. Similarly to previous studies, they consider the effects of place of articulation, contextual factors (including vowel), stress, and word-position. Based on an analysis that also discusses phonological implications, they report on a hierarchical organization of obstruents from voiceless stops to voiced approximants. A scale that includes six degrees of aperture shows gradual differences according to stress and word position effects along the hierarchy. The authors state that these results for Canary Islands Spanish show that lenition processes yield a partial overlap between underlying phonemes and surface realizations, although the phonological contrast between voiceless and voiced stops is largely maintained.

Although less relevant to the research in the present study, the Spanish stop lenition literature also includes other approaches to the phenomenon that are oriented to language change, language acquisition and/or sociolinguistics. Previous studies discussing diachronic approaches to Spanish phonology also turn their attention to different varieties of Spanish and phonological processes that include allophonic variation. Thus, Central American reports on allophonic distribution of /b, d, g/ can be found in Amastae, 1989; Fernández, 1982 and Lipski, 1994. These studies focus, for example, on how voiced plosive lenition was restricted to intervocalic positions to evolve to a wider distribution affecting CC sequences in more recent developments. Another area that has included Spanish stop lenition as the focus of attention is language acquisition studies and how learners manage differences between voiced plosive realizations and approximants. These studies may refer to the role that native structures play in the acquisition of Spanish voiced stops in English learners of Spanish as a second language, and they may also focus on heritage Spanish and the interactions with English in the production of voiced plosives (See Botella, 2015; Face & Menke, 2009; González-Bueno, 1995, and Zampini, 1996).

1.4 Phonological approaches to Spanish stop lenition

From a phonological point of view, an extensive literature can be found that offers different accounts of Spanish stop lenition. Traditional accounts, such as generative and autosegmental approaches basically view the phenomenon as an alternation between voiced stops and spirantized realizations in the given contexts. Generative Phonology describes sound alternations as language-specific rules that convert underlying segments from one sound class to another, based on the particular phonological context in which the change occurs. The classic study on Spanish phonology by Harris (1969) specifically refers to "spirantization" as an alternation between voiced stops and their [+continuant] allophones according to contexts. The rule specifies that they are realized as [-continuant] in word-initial position as well as in homorganic sequences and after non-continuant sonorants, while they are [+continuant] elsewhere in two types of speech (andante and allegro) that would correspond to casual speaking style. Non-linear, autosegmental approaches (Goldsmith, 1981; Hualde, 1989) describe lenition processes by proposing a rule that spreads a [+continuant] feature in the adjacent segment to the underlying obstruent. Mascaró (1984) also proposes a spreading rule that can account for stop lenition processes in Spanish, Catalan and Basque.

As mentioned in Section 1.2 above, some of those early, traditional studies on Spanish stop lenition also show an interest in focusing on the interplay between phonological assumptions and observed phonetic facts. For example, Harris (1969), Navarro-Tomás (1971), and Torreblanca (1980) focus on providing an account for the distribution of voiced plosive allophones by reporting on spectrographic observation of their features, although emphasis lies on the importance of the phonological environment. Similarly, diachronically-oriented approaches view lenition as a step toward deletion (Bauer, 1988; Escure, 1977; Hock, 1991). Although this view allows to predict some features of the resulting realizations of weakening processes, such as duration, it has been argued that it cannot account for other phonetic features expected, such as the degree of closure (Lavoie, 2001). However, in the line of the Neogrammarians, Hualde, Simonet & Nadeu (2011) claim that although Spanish stop lenition is accepted to be a gradient phenomenon affecting contexts differently, it finally becomes a regular process. They add that, in order to provide a complete account of this type of processes, two further steps are necessary: conventionalization and phonological recategorization. Bauer (2008, p. 611), in a revision of her previous work

(1988), also proposes a definition of lenition as a "failure to reach a phonetically specified target", in an attempt to cope with observed lenition and fortition processes in sound change that may be in progress or completed.

Another approach that has become relevant to Spanish stop lenition is based on the postulates of Optimality Theory (OT). This phonological theory (McCarthy and Prince, 1993; Prince and Smolensky, 1993) assumes that phonological processes are a result of the interaction of universal constraints. These constrains are viewed as opposing forces that may conflict with each other and then resolve tension in different ways according to ranked solutions. For example, Kirchner (1998, 2004) claims that each consonant requires some effort in order to be produced, and he assigns an effort value to consonants according to the LAZY restriction, which penalizes effort. Thus, these constraints are ranked according to the amount of articulatory effort for a given sound according to the context where it occurs.

Other accounts on Spanish stop lenition under Optimality Theory views focus on how the continuancy feature is specified. Martinez-Gil (2003) and González (2002) state that the continuancy specification of the surface consonant depends on contextual features and they propose a constraint for stops after vowels and continuant consonants. In similar lines, Colina (2020) explains that the underlying representation of Spanish voiced obstruents is underspecified for continuancy, and the corresponding value is provided by the phonetic realization. Colina (2016) previously describes underspecification in OT terms in that it involves absence of specification, which persists into the output of the phonology. This output is selected by the constraints in a particular sequence to produce the optimal output, which is assigned degree values by the phonetics. She states that this description accounts for the alternation between different voiced stop realizations.

Although these approaches based on Optimality Theory seem to account for shorter durations and decreased constriction degrees of spirantized realizations (see also Piñeros, 2002), they have also raised some criticism. It has been claimed that differences in effort between lenited and unlenited productions are not important enough to motivate consonant weakening (Kingston, 2008). In addition, with respect to stop lenition in Spanish, it has been argued that some of the predictions based on effort reduction approaches, such as the effects of vowel contexts do not seem to be consistent with actual results (Colantoni & Marinescu, 2010; Kingston, 2008). From an articulatory perspective, Recasens (2015) also criticizes OT effort-based approaches and how they can account for lenition processes. He argues that if minimization of articulatory effort and decrease in articulatory displacement are related to effort reduction, stops are expected to lenite more clearly next to open vowels than to close vowels, which has not been reported to be so in different studies (Hualde, et al 2010). He also suggests that effort-based approaches do not appear to be suitable to account for lenition in heterorganic CC sequences as opposed to homorganic clusters, where effort is expected to be minimized.

Finally, consonant lenition has also been approached from the viewpoint of decreased gestural magnitude and reduced duration. Supporting this approach and as a basis for phonetic predictions, Articulatory Phonology (Browman & Goldstein, 1989, 1992) postulates that the basic units of phonology are articulatory gestures which are coordinated according to different temporal arrangements during the production of speech. This notion of gestures is crucial in that time is an intrinsic feature that contributes to explaining how spatio-temporal changes determine phonetic behaviour. Based on the theory of task dynamics, a gesture is conceived as a combination of coordinative structures each of which aims to reach a goal (Saltzman, 1991). Gestures unfold into events in the vocal tract under the action of the speech articulators, with the corresponding resulting articulatory configurations, named a tract variable. Thus, tract variables involve the action of a set of articulators, namely, the lips, the tongue tip, the tongue body, the velum and the glottis, and they are defined by two primary dimensions: constriction location and constriction degree.

Besides being the central notion to phonetic description, gestures are also the basis for phonological contrast and are different as long as they have different compositions, involving presence or absence of a single gesture or different assemblies. Thus, gestures involve the action of mechanisms that can account for different phonological processes, namely, overlap and blending of articulatory gestures, and reduction in gestural magnitude. More specifically, they suggest that gesture overlap may result in decrease of gestural magnitude, which may prevent target accomplishment. This particular view can provide the grounds to account for lenition processes as a consonant failing to reach its target (Honorof, 2003; Lavoie, 2001; Parrell, 2010; Romero, 1995). Moreover, it has also been argued that constriction degree and duration go along in voiced stop weakening in Spanish (Lavoie, 2001; Recasens, 2002; Romero, 1995), and it is argued that it can be accounted for as a result of gestural overlap (Romero, 1992). Iskarous & Pouplier (2022) emphasize that

Articulatory Phonology and Task Dynamics have had a strong influence in the field of phonetics in the last 20 years. They review the key areas that have become central to speech production from this perspective (contrast dynamics, prosodic dynamics and planning dynamics) in an attempt to describe and evaluate the evolution of the theory in the 21st century. For the purpose of this study, it is believed that the general views provided by Articulatory Phonology constitute an appropriate framework for the observations presented.

1.5 Analysis methods and procedures in the study of Spanish stop lenition

One of the relevant issues in Spanish stop lenition is the method employed to collect relevant data that allows to observe the phenomenon appropriately. Most well-known phonetic accounts of voiced stop lenition in Spanish are based on acoustic analysis, while much fewer studies rely on articulatory data. For example, Hualde, Shosted & Scarpace (2011) and Lavoie (2001) combine acoustic and electropalatographic data in their descriptions of Spanish stop lenition, while Recasens (2015) relies on acoustic and eletroglottographic data to provide information on the action of the larynx. Parell (2010) and Romero (1992, 1995, 1996), use electromagnetic articulometry (EMMA), which allows to track the movement of articulators. This technique employs a number of coils attached to different points on the articulators, and transmitters that allow the generation of the corresponding distance signals based on coil movement. Still, more recent studies (Brós & Krause, 2023) complement acoustic analysis with facial behaviour analysis software. More specifically, OpenFace 2.0 has been used, which allows to track landmarks and head poses to picture the movement of the lips and the jaw. The corresponding segmentation performed on the acoustic signal can be synchronized with the video recording that tracks de landmarks on the face image, providing articulatory data for the sequences under study. These studies have very valuably contributed to shedding light on the nature of stop lenition processes and to complementing the acoustic data provided, raising more and more interest in combined technologies for experimental phonetics.

Still, a lot of the research reported is based on acoustic data and acoustic analyses that have become more sophisticated and accurate as tools have been improved. Although the acoustic cues that provide evidence of the features of lenited realizations are quite consistent and reliable in the various accounts, analysis has evolved towards the complementary observation and investigation of several acoustic parameters (Hualde et al, 2010; Kingston, 2008, Ortega-Llebaria, 2003; Soler & Romero, 2013). The choice of acoustic cues to analyse lenition processes has shifted towards including different parameters based on the intensity curve that can provide more accurate measurements on specific acoustic cues of consonant features associated with lenition processes. The present study relies on some of those parameters as explained in detail in Chapter 2.

1.6 Research hypotheses

In this study, it is hypothesized that the principle underlying voiced stop lenition in Spanish involves decreased gestural magnitude whereby the target realization is undershot and so is not completely achieved due to timing constraints. The resulting realization thus shows reduced constriction degree and reduced duration, which would go along in this phenomenon. In the line of previous studies, the present investigation provides acoustic data of the distinguishing features of lenited realizations, aiming to show how the variability exhibited in spirantized consonants depends most importantly on timing constraints and contextual conditions. With these fundamental assumptions, this study presents the following research hypotheses.

1.6.1 Spanish voiced stop lenition as a gradual, phonetic-based process

The traditional so-called plosive-spirant alternation in Spanish is a gradual phenomenon which is better described as a weakening process that depends on a number of factors. Although the gradual nature of the phenomenon has been suggested and illustrated in previous studies, interest lies on some specific effects of contextual factors that favor lenition as opposed to those that favor more variability in the resulting realizations. Very often, these studies emphasize the importance of phonological categorization based on the observed variability, as shown throughout the present chapter. From a phonetic perspective, the present study investigates the following hypothesized assumption:

a) Coarticulation effects and variability in voiced stop lenition are driven by the interaction of some given conditions that operate in the process regardless of phonological categorization premises. It is hypothesized that the process is phonetic-based in that, besides contextual conditions, it is importantly determined by other factors intervening in consonant weakening phenomena, namely, the role of time.

1.6.2 The effect of time and its interaction with contextual factors

Based on the above assumption, lenited realizations in Spanish stop lenition may show different degrees of constriction motivated by different factors, among which flanking segments seem to stand out. Variability has also been shown to be conditioned by speaking rate, and previous studies have explored the effect of the temporal dimension in stop lenition processes in Spanish (Soler & Romero 1999, 2013; Romero & Soler, 2019). The present study seeks to further investigate the role of time and contextual factors by providing more evidence on the following hypothesized assumptions:

a) Speaking rate determines the constriction degree of the resulting realizations in voiced stop lenition processes, and it can show the crucial role of time in stop lenition in Spanish. The constriction degree of the spirantized consonant is conditioned by the time the speaker employs to address the complete closure of the target voiced stop consonant, which is undershot due to time constraints. Thus, it is hypothesized that slow speaking rates will favour more occluded realizations. It is assumed that consonant duration and constriction degree go along in the phenomenon.

b) Speaking rate is expected to condition the variability observed in relation to contextual factors. If the time span devoted to produce C+voiced plosive or V+voiced plosive sequences is extended, it is hypothesized that coarticulation effects will modify the variability associated to contextual factors in Spanish voiced stop lenition.

In order to test the above hypothesized assumptions, evidence should be provided to demonstrate how Spanish stop lenition phenomena are affected by different conditions. One of the crucial tests is to show how consonant weakening may fail due to time constraints, allowing the voiced stop counterpart to surface instead. Two different speaking rates are necessary to test this time dimension. Evidence is also crucial to test the effect of contextual factors, and investigate their behaviour as a function of time. So, the present study is intended to test how slower speaking rates affect spirantized realizations, even across the contexts where lenition is the common outcome.

Based on the presented premises, the remaining chapters of this dissertation first cover the experimental procedures adopted in the collection and the analysis of data in

Chapter 2. Chapter 3 presents the results of the experiments conducted with details of the inferential statistical analysis. Finally, Chapter 4 is devoted to evaluating the results in the light of the research hypotheses presented in this chapter. The final chapter also provides some rationale concerning the appropriateness of Articulatory Phonology to account for the processes observed in Spanish voiced stop lenition from a phonetic perspective, and draws some final conclusions about the research developed in this dissertation.

Chapter 2 Method

The present chapter describes the experimental procedures implemented to test the hypothesized assumptions on the role of time in Spanish stop lenition. Generally, it was predicted that voiced plosives in Castilian Spanish undergo a lenition process that, to a great extent, depends on timing constraints in their realization. Consequently, when different speaking rates are used in the production of voiced plosives, it is predicted that different resulting constriction degrees will be observed, with more lenited realizations produced at faster rates. Thus, the experimental design, data collection, and data analysis procedures were devised and tools were selected to allow the testing of those predictions. Acoustic analysis was chosen as the experimental procedure, since it is believed that the extraction and analysis of acoustic cues of constriction degree, based on reliable analysis software, can provide the necessary evidence to support the hypotheses presented in this study. These experimental procedures are described in this chapter, and are organized as follows. Section 2.1 describes the experimental design, while Section 2.2 explains data collection procedures. Section 2.3 focuses on data inspection as the preliminary stages of data analysis. Section 2.4 describes the details of acoustic analysis and segmentation procedures. Finally, Section 2.5 explains the decisions taken for the statistical analysis.

2.1 Experimental design

Based on the stated assumptions, this study aims to provide a thorough, systematic analysis of Spanish stop lenition by devising an experimental design that allows to control data and procedures in various ways. One of the most important decisions made concerning the foundations of the experiment involves the use of laboratory conditions to collect the data under study. The design is thus based on laboratory recordings, where scripted stimuli are used, as opposed to casual speech data or other spoken corpora. This decision is made to ensure the occurrence of all the variables required to test the hypothesis and minimize the effect of unexpected events.

Another decision that determines the overall shape of the study is the choice of data analysis approaches and tools. As reported in Chapter 1, acoustic data and acoustic studies have most often been the choice in previous studies to provide the experimental evidence that reports on the features of Spanish stop lenition. It is also true that acoustic analyses have evolved to show how multi-parametrical investigation results in a more faithful observation of events. In particular, the acoustic analysis procedure devised in this study is inspired on previous works (Hualde et al., 2010; Kingston, 2008; Parrell, 2010) to ensure reliable examination of facts. Firstly, it uses acoustic correlates of consonant weakening that have been reported to match articulatory evidence of the phenomenon. Secondly, it relies on a systematic procedure that avoids the inconsistencies and inaccuracies of manual segmentation of the acoustic signal when spectrographic images do not show distinct events due to coarticulation effects. This procedure is based on calculations performed on Praat (Boersma & Weenink, 2024), the speech analysis tool chosen for the study (as explained in section 2.4).

Finally, among the general decisions involving analysis procedures and tools, both quantitative data and qualitative illustrations are provided to support the hypothesized assumptions. Quantitative data include the values obtained in the measurements performed on the selected acoustic cues. These values constitute the main variables considered in the study and results are based on their behaviour. In addition, quantitative data are also provided to validate the results in the light of statistical analysis. Qualitative illustrations, in turn, consist of the spectrographic images that, besides the selected variables, show key features of Spanish voiced plosives and spirantized realizations. Details of the procedures implemented to show all these aspects (both quantitative and qualitative) will be presented in the remaining sections of the current chapter.

2.1.1 Subjects

The present study focuses on Peninsular Castilian Spanish, so the subjects that participated in the experiment were native speakers of Castilian with no relevant influence of other languages. Six subjects, three males and three females (ages 23 to 37), participated in the experiment: FR, EM, DG, PI, PM and MC. They were all born in Madrid, except for DG, who was born in Segovia (central province in Spain) and MC, who was born in Majorca (Balearic Islands). Before the experimental sessions, subjects were asked to answer a questionnaire[1], where they all reported not to have any influence of other languages (especially those spoken in Spain) or significant influence of other varieties of Spanish (see Table 2.1). Indeed, MC, although born in Majorca,

[1] The complete questionnaire administered can be found in Appendix A

reported that her mother tongue was Castilian Spanish and that she had had very little influence of Majorcan Catalan. In addition, they had all lived in Madrid most of their lives. At the time of recording, five of the speakers lived in Madrid and one of them lived in Barcelona, but he had very little influence of Catalan, if any.

Prior to the recordings, face-to-face interviews were also held with the participants in order to expand or clarify their answers to the questionnaire and identify other features that could potentially have some effect on the intended study. Through these conversations, subjects revealed their dialectal patterns and other pronunciation features. The general impression was that no patterns or features of pronunciation concerning age, sex, geographical origin, knowledge of other languages, education or profession suggested any relevant facts that could prevent them from participating in the experiment. In addition, none of the subjects reported having any visual, hearing or speaking impairments, and they had not taken part in similar experiments. In fact, at the time of the recordings, they were not aware of the specific purposes of the experiment, and they were informed of them generally after the recording sessions were over.

Table 2.1

Subjects' Information Considered for Experimental Purposes

Subject	Sex	Age	Accent (self-identified)	Residence
FR	M	24	Castilian	Madrid
EM	F	28	Castilian	Madrid
DG	M	36	Castilian	Central Spain (1973-2004) Barcelona (2004-2010)
PI	F	23	Castilian	Madrid
PM	M	34	Castilian	Madrid
MC	F	22	Castilian	Majorca (1987-1997) Madrid (1997-2010)

2.1.2 Stimuli

One of the crucial issues that arose as the experiment was designed was how to control for both speaking rate and the variety of contexts that could provide a complete picture of Spanish stop lenition. As mentioned above, data from casual speech in conversation and recordings of more formal speech (mass media, academic speech, etc.), as well as other spoken corpora could constitute an appropriate source. However, the occurrence of potentially-lenited instances could be controlled only to some extent. Thus, they were discarded, as speaking rates had to be carefully controlled to provide consistent data. Instead, laboratory conditions were chosen and materials were based on scripted stimuli that had to be read and recorded.

Despite the choice of controlled conditions in the laboratory, the selection of stimuli still posed a problem concerning the type of words. In order to observe consonant weakening inside words, it was necessary to select a list of tokens that included the range of contexts where the phenomenon occurs, so a consistent list of stimuli was required. However, the occurrence of real words that follow a systematic patterning by number of syllables, vowel type and contexts could not be ensured, since some of them cannot be found in the language. Therefore, for syllable onset positions, the final decision was to use non-words as stimuli on the grounds that they have been used successfully in other studies on stop lenition (Romero, 1995, 1996). Although lexical frequency has been suggested as a factor that may have an effect on coarticulatory patterns (Recasens, 2018), it is believed that the sequences chosen agree with the phonotactic structures of Spanish. Besides, as Hualde, Simonet & Nadeu (2011) suggest, stop lenition in Spanish does not have lexical exceptions and occurs both word-internally and across boundaries and it has become a regular process. Thus, it can be assumed that non-words will undergo the same lenition process as real words, as they are also similar to the real words of the language. In fact, subjects reported that the non-words selected followed the patterns they recognized for Spanish words and had no problem in integrating them in a sentence.

Bearing in mind these considerations, the complete stimuli inventory included the most common environments where stop lenition has been reported to occur, and it was built up according to some conditions as follows:

a) Choice of non-words to control the syllabic pattern and vowel contexts
b) Selection of contexts to provide a complete range of flanking segments
c) Position in word: medial position, to control the flanking segments
d) Position in syllable: onset

Thus, in order to cover the whole range of potential spirantized cases, the design of the experiment includes four independent variables: place of articulation, flanking vowel, flanking consonant and speaking rate. The place of articulation variable includes three points of articulation: labial /b/, dental /d/ and velar /g/. The flanking vowel variable includes /a/, /e/ and /u/ in order to observe the influence of vowel features on the lenition patterns exhibited by /b/, /d/ and /g/. The flanking consonants, in turn, include the sequences fricative+C, rhotic+C, lateral+C, and the control group nasal+C, where lenition is not expected to occur. Additionally, the corresponding voiceless stops (/p/, /t/ and /k/) are also included for the different contexts to compare them with resulting realizations of stop lenition processes. Table 2.2 shows the selected variables for the choice of items in the inventory, together with the actual non-words included in the design. Altogether, the inventory resulted in a total of 540 tokens, since it included 18 words by three vowels and by ten repetitions. That was further multiplied by two speaking rates.

Table 2.2

List of non-words containing /b d g/ in onset, medial stressed position

POSITION	LABIAL	DENTAL	VELAR
INTERVOCALIC	tabapa	tadapa	tagapa
(VCV)	tebepe	tedepe	teguepe
	tubupu	tudupu	tugupu
AFTER LATERAL	talbapa	taldapa	talgapa
(VLCV)	telbepe	teldepe	telguepe
	tulbupu	tuldupu	tulgupu
AFTER NASAL	tambapa	tandapa	tangapa
(VNCV)	tembepe	tendepe	tenguepe
	tumbupu	tundupu	tungupu
AFTER RHOTIC	tarbapa	tardapa	targapa
(VRCV)	terbepe	terdepe	terguepe
	turbupu	turdupu	turgupu
AFTER FRICATIVE	tasbapa	tasdapa	tasgapa
(VSCV)	tesbepe	tesdepe	tesguepe
	tusbupu	tusdupu	tusgupu
VOICELESS STOP	tapapa	tatapa	tacapa
(VOV)	tepepe	tetepe	tequepe
	tupupu	tutupu	tucupu

Concerning the complete set of tokens, it must be mentioned that although all these experimental materials were included in the design and in the recording sessions, the analysis focuses on two vowels (/a/ and /u/). It is considered that the selected vowels can contribute to placing the required emphasis on the time factor, without further analysis of the vowel context.

2.2 Data collection procedures

Data were collected in three recording sessions that were carried out in two different locations over a period of two months, according to the planned procedures. The data for one of the subjects that participated in the experiment (DG) was collected in the Speech Analysis Unit at *Universitat Rovira i Virgili* in Tarragona (Spain), while the rest of the experiments were conducted in the Laboratory of Phonetics of *Centro Superior de Investigaciones Científicas* (CSIC) in Madrid[2] (Spain).

In order to collect the data, the recording sessions were carefully planned to allow participants to read a considerable amount of tokens comfortably. The selected non-words (see Table 2.2) were to be read at two different rates and for a total of 10 repetitions each, so they had to be organized and presented in such a way that the subjects could read them with the necessary breaks to complete the session. With this purpose in mind, and to make sure that the number of repetitions was under control, the total of 540 tokens were organized into five files including 108 tokens each. Every file contained two of the ten repetitions that were planned to be collected. The 108 tokens that were included in each of the files were randomized first and were used to cover the two speaking rates. In spite of the number of tokens, those files could be handled quite comfortably by the subjects and the researcher.

According to the random order obtained, the tokens were organized into two sets of five PowerPoint files each, one for each speaking rate[3]. These included the five files for the complete inventory. The tokens were presented in the carrier sentence "*Diga* _______ *cada vez*". One separate slide was used for each token and sentence, and slides were automatically displayed on a computer screen so that the subjects could read them one by one with no listing effects. Each file included 21 five-slide groups,

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[2] The Laboratory of Phonetics is located in the Centre for Human and Social Sciences (CCHS) of the Spanish National Research Council (CSIC) in Madrid.

[3] Details of stimuli presentation can be found in Appendix B

one three-slide group plus an extra five-slide trial group at the beginning, which was also recorded, although not included in the analysis. Besides helping to control the number of repetitions, the PowerPoint presentations also helped to time the reading pace and thus control the two speaking rates. Since speaking rate constitutes a crucial factor in the study, the two rates were carefully chosen to allow the subjects to handle them. The fast rate would correspond to casual, fast conversational style, while the slow rate would be used in formal, emphatic pronunciation.

In order to collect the necessary data, the complete experimental session required participants to spend a long session in the laboratory, which entailed taking care of the different stages and helping subjects complete the session at ease. Participants were asked to send their questionnaires previously to the experimental session so that they could avoid spending unnecessary time in the laboratory. Four of the participants were able to send their questionnaires, while two of them filled it in before the experiment began. Based on the questionnaire, a short interview was held with all participants to clarify any data provided in the questionnaire and to identify potential problems and difficulties, as mentioned in section 2.1.1 above.

After this short interview, and before the recording actually began, the subjects were given detailed explanations about recording procedures, both orally and in writing. These included procedures with the use of PowerPoint files, timing adjustments and recommendations on pace and rhythm for the different speaking rates. The main purpose was to ensure that the long recording session had no unexpected difficulties and participants could feel comfortable enough to complete it. It was believed that reading instructions, besides getting any clarifications, would help them focus on important facts about the recording session. These instructions also included discussing any aspects involved in stimuli presentation on the computer in order to elicit any questions or problems.

Besides dealing with instructions and recommendations, this preliminary contact with materials and procedures also helped participants to reduce anxiety and to adapt to the recording equipment as necessary for each of them. It was taken into consideration that the session required some concentration and subjects had never participated in a similar experiment. Thus, they were able to ask for any clarification, and they also tried reading the extra trial sentences on a PowerPoint file before starting the recording so that they could check how they would attempt the different rates and paces. The time spent on giving instructions, checking the appearance of stimuli and trying speed and pace also allowed for seat and body positioning, and microphone and volume adjustments on the part of the technician that assisted with the data collection sessions. Altogether it helped participants become familiar with the dynamics of the recording procedure.

Slide presentation allowed to sequence tokens at two different time intervals to obtain two speaking rates that could be as consistent as possible across subjects. For all the PowerPoint files, tokens (slides) were sequenced at three-second intervals for the slow rate, while fast tokens appeared at 1-second intervals. Every five-slide group was followed by three slides that appeared at one-second intervals. These slides indicated that the subject could stop reading for three seconds and had to get ready for the next group of five tokens. After each file was read and recorded, participants could rest for about two to three minutes before they started reading the following file. Rest time was also used to discuss any difficulties, and especially to provide some feedback on the different speaking rates employed. The total time involvement required of each subject to record all data was 23 minutes for the fast repetitions and 42 minutes for the slow tokens. These times included the five-slide trial block. Rest time pauses between files totalled around 30 minutes and the added instructions session at the beginning took around 10 minutes. The total number of tokens that each subject read was 1,080.

Data collection followed similar procedures in both locations where the experiments were conducted, although the recording equipment was different. In the URV Speech Analysis Unit, an M-Audio Nova condenser microphone was used, with an M-Audio Firewire Solo mobile interface, and data were digitized on a Macintosh computer using the Praat speech analysis software package (Boersma & Weenink, 2024). In the Laboratory of Phonetics at CSIC, an AKG C444L cardioid condenser headset microphone was used, and data was digitized on an Alesis MultiMix 16USB mixer with USB audio, using Adobe Audition 1.0 audio editor. All the audio data in the different sessions were digitized at a sampling rate of 44.1 kHz and 16-bit sample resolution, and were recorded in a soundproof booth for the best possible quality under laboratory conditions.

During the recording sessions, it was the responsibility of the researcher to control that all tokens were read with no potential problems for the subsequent analysis, while the control of the technical aspects was left to the sound technician. In the case of reading and pronunciation, it was crucial to identify any important problems that would require taking some action. Generally, there were very few incidents and when identified, the participant was asked to add some repetitions if considered necessary. Some slips of the tongue occurred occasionally and for four of the subjects these could be solved easily by asking them to read the specific slide group again to repeat the problematic token. However, two of the subjects (MC and PM) had some difficulty in reading some of the tokens and/or reading at one of the rates, and they were asked to repeat on various occasions. PM was asked to repeat a whole file of the stimuli groups. As far as technical aspects were concerned, no incidents occurred, and the technician made sure that the data were being recorded and saved properly after participants had read each file.

2.3 Data inspection

After the recording sessions were over, and prior to starting any analysis, the data were inspected from various angles. First, it was considered necessary to check that data actually met accuracy requirements and that there were no important problems in the production of the required tokens. It was assumed that although the recordings were carefully controlled, a big amount of data had been recorded, and auditory inspection of all the productions was necessary in case some tokens had to be discarded. Subsequently, all the tokens were displayed on Praat to be observed for the purpose of inspecting general features of different realizations at the two rates. At this stage, it was also necessary to select the relevant cues for consonant constriction, which would be measured in the analysis.

2.3.1 Auditory inspection

After the observation of facts and detection of potential problems during the actual recording sessions, further auditory observation was carried out to identify any mispronounced tokens. The audio files recorded were played and listened to carefully, and some tokens had to be discarded at this early stage. As mentioned above, one of the speakers (PM) was asked to repeat and record a complete PowerPoint file in the inventory. He found it especially difficult to read words at the fast rate and made a number of mistakes caused by slips of the tongue. In some cases, he confused one target token for another, with the corresponding self-correction in some cases and without correction in others. Although less importantly, this was also the case of the rest of speakers, who mispronounced some tokens for similar reasons.

Besides predictable difficulties and inaccuracies, some unexpected pronunciation facts were identified that could have some effect for the purpose of the study. A more important problem was identified for PM, since he overemphasized the pronunciation of fast tokens, which was expected to be avoided in order to achieve a casual, common fast speaking rate. This pronunciation feature may not constitute an accuracy problem, but it was a factor that may play a role in lenited realizations, that is, overemphasizing for accuracy. Similarly, as audio files were inspected, another subject (MC) was found to have difficulties reading some of the files. In this case, she could not read many of the slow tokens without making pauses, which in a number of tokens resulted in some realizations that could be different from the rest. Her production (volume, articulation) was extremely tentative, and in many cases her voiced faded away in the middle of the sentence. Repetition did not seem to solve the problem for these participants.

In addition to these problematic cases, another fact was identified, which had not been spotted at the time of the recording. One of the subjects (EM) showed a pronunciation feature that was not apparent as the recording session was monitored. EM did not pronounce one of the sequences under study correctly: VLCV. As her files were inspected against the actual PowerPoint file presentation, it was noticeable that some VLCV tokens were pronounced as VRCV. She seemed to have problems to pronounce VLCV accurately at a fast rate. For example, she read "*tarbapa, targapa, turbupu, terguepe, and turgupu*" instead of "*talbapa, talgapa, tulbupu, telguepe and tulgupu*". This confusion (or slip of the tongue) did not occur so often in the case of /d/, and was not a problem in the case of the slow rate. However, the rest of cases were so many that a final decision was made to discard the realizations for this context for EM. For the purpose of the statistical analysis, this meant fewer items (repetitions) for the case of VLCV but in the context of the model chosen this does not represent an imbalance that could make results less reliable.

After all the recorded files had been inspected to detail, and in order to avoid including an important number of mispronounced tokens, some experimental material had to be discarded. First, it was considered appropriate to discard PM's and MC's files completely because the inaccuracies observed in their productions had a direct effect on the focus of the study; that is, inaccurate tokens affected a number of productions across speaking rates, which would alter the number of tokens at both rates substantially. It was also assumed that data for four speakers would be effective enough, considering the number of tokens collected for each participant. After having discarded the data for PM, MC and the VLCV context for EM, a few more random inaccurate tokens had to be discarded, especially for the fast rate. Altogether, the evaluation of data for correctness was considered acceptable as some inaccuracies were expected, especially acknowledging that reading at different rates (especially the fast rate) entailed some difficulty.

2.3.2 Acoustic signal inspection

Inspecting data also involved checking the features of voiced plosives and lenition features on the spectrographic images corresponding to participants' realizations. A number of tokens by the four participants were selected randomly and viewed for an initial acoustic inspection. It could be observed that images corresponded to the description of Spanish voiced plosives and spirantized realizations of voiced plosives. As described in previous work on Spanish spiratization (Martínez Celdrán, 1991, 2013; Hualde, 2005), voiced plosives are realized without complete occlusion (often referred to as approximants) in many contexts, and constriction degrees may vary considerably according to different factors. From lenited, vowel-like realizations to closer plosive productions, a range of realizations were soon revealed. Figure 2.1 shows an open (lenited) production of "tugupu", where the open realization of /g/ resembles that of a vowel, while Figure 2.2 shows a closer realization of "tugupu" with a clearer closure.

Figure 2.1

Spectrographic image of "tugupu" (fast)

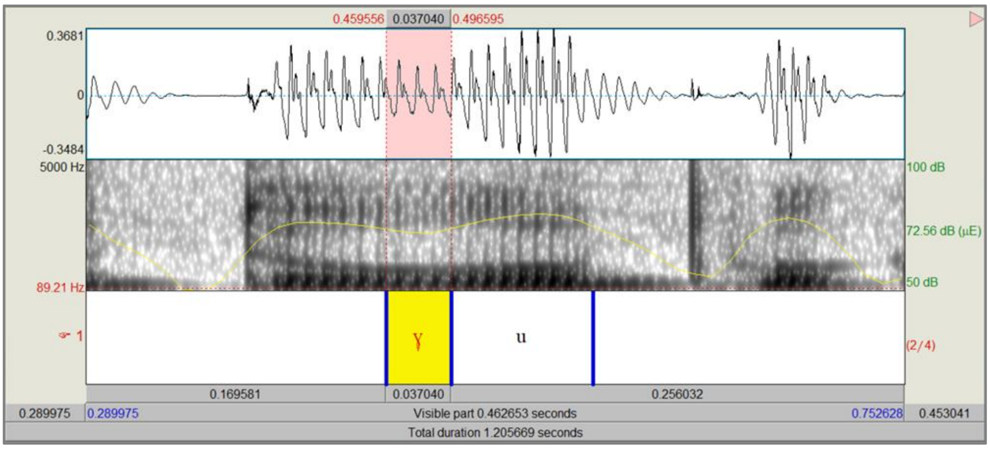
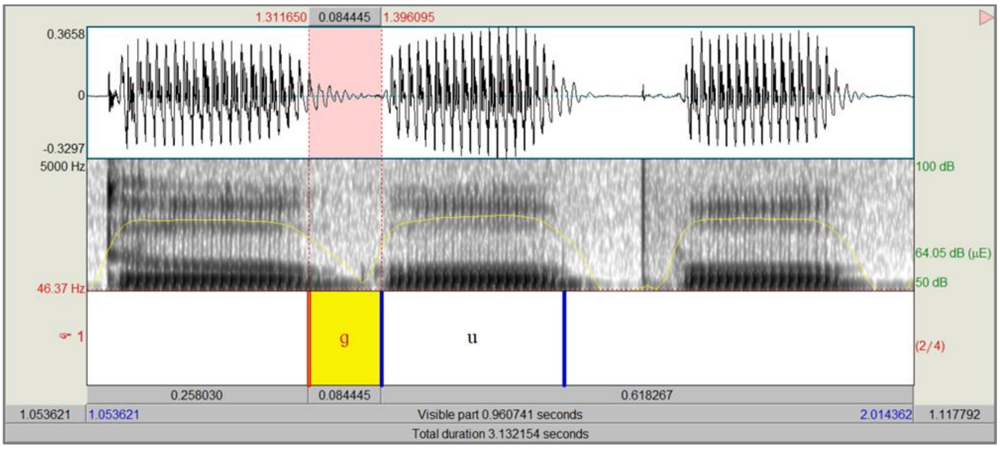


Figure 2.2

Spectrographic image of tugupu (slow)



General acoustic descriptions of Spanish voiced plosives include two main features that show the differences between open and close realizations. As shown in Figure 2.1 and Figure 2.2 above, consonant durations are clearly different in the two different realizations, where [g] is longer than [ɣ̞]. Another difference based on visual observation only is shown by the intensity curve (yellow line), which dips to lower values for /g/. Higher intensity values are driven by the existence of higher levels of acoustic energy in the case of [ɣ̞], which constitutes another relevant feature of lenited voiced plosives in Spanish. These parameters comprise the acoustic cues selected to analyse participants' realizations of voiced plosives at different speaking rates and to observe different consonant constriction degrees. These analyses are also accompanied by qualitative illustrations shown in the spectrographic images: formant structure and occlusion.

2.4 Acoustic analysis and segmentation procedure

As mentioned above, there has been general agreement concerning the basic acoustic correlates of Spanish voiced stop lenition, and studies have focused mainly on duration and relative intensity of the target consonant. More recently, acoustic analysis has shifted towards adding more parameters or to refining some aspects of the analysis (Hualde et at., 2010; Kingston, 2008, Soler & Romero, 2013, Romero & Soler, 2019). In this line, the present work aims to provide a systematic analysis and present an accurate description of the results of spirantization and the effect of selected factors.

This analysis is supported by Praat tools that can provide precise calculation and extraction of the required acoustic measurements, values and features.

One of the parameters that have deserved attention in order to obtain more accurate measurements is relative intensity. Various methods have been proposed to measure intensity: intensity ratio, intensity difference and maximum rising velocity, and they have been used in various studies on Spanish stop lenition. For example, intensity ratio is used in Romero et al. (2007) and Carrasco (2008), while intensity difference is used in Hualde et al. (2010), Martínez-Celdrán & Regueira (2008), and Soler & Romero (1999). Maximum rising velocity is also used in Hualde et al. (2010) and Kingston (2008) quite similarly. With respect to these methods to measure intensity, Parrell (2010) claims that the most accurate measurement is intensity ratio as observed in a study where he compares these acoustic measurements with articulatory measurements for the same tokens, using electromagnetometry. Following these results, this is the method chosen in the present study, which was already shown in Romero & Soler (2019).

In addition to discussed issues on methods of measuring intensity, there is a procedural aspect that has driven attention in the segmentation of target lenited consonants. Previous acoustic studies on spirantization and consonant weakening were based on manual segmentation to select the consonants under study. While manual segmentation has yielded reliable results, some attempts have been made to avoid inconsistent decisions when it comes to establishing boundaries between sounds like glides, vowels and lenited consonants. For example, Lavoie (2001) refers to the difficulty of manual segmentation for some sounds, and she carefully justifies the adopted criteria. Kingston (2008) avoids manual segmentation and he uses the intensity values for maximum and minimum velocities to extract durations. For the purpose of the present study, a procedure that provides automatic segmentation is implemented in an attempt to obtain accurate measurements of the target consonants, both for duration and relative intensity.

Based on these considerations, the acoustic approach presented in this study proposes an analysis which, inspired on previous work, tries to enhance the analysis by avoiding manual handling of the acoustic signal. It was believed that the observed different constriction degrees required a systematic procedure that could provide consistent segmentation, especially in the case of open realizations. This analysis required careful planning of the procedure and the subsequent development of an adhoc Praat script (see Appendix C) to automatically extract the values for the selected acoustic cues of consonant constriction degree, which constituted the dependent variables in the study.

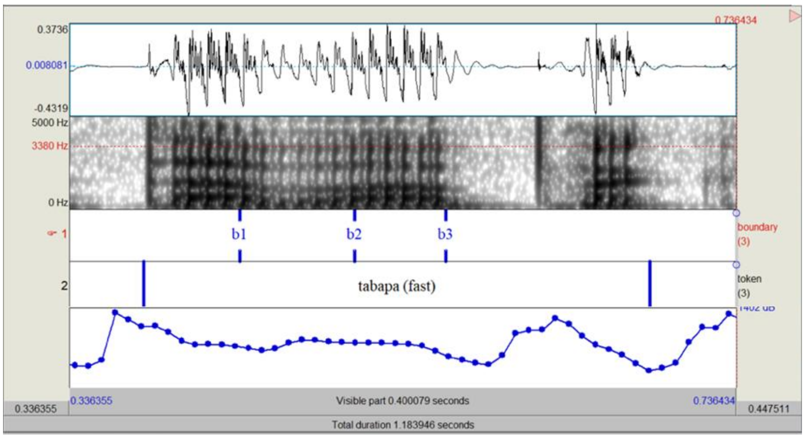
Scripting required to automate the analysis process as much as possible in order to handle the number of tokens under analysis. This automation also involved scripting various stages that would provide the corresponding values and show images of the corresponding selections most conveniently. The principal fact in the Praat routine was to include a command string to calculate the first derivative of the intensity curve, which shows how much intensity changes as a function of time. Minimum and maximum values shown by the derivative in the transitions from and to flanking segments provided the points for segmentation. These points were taken as reference to calculate the duration of the consonant and to calculate intensity ratios between the consonant and the vowel. Three main stages were considered necessary to obtain the relevant data, and they involved different methods:

1. Editing and viewing the corresponding Praat screens to make acoustic data ready for data extraction.
2. Selecting approximate boundaries for main events (consonant and vowel) on Praat text grids.
3. Selecting the consonant segment and extracting consonant duration based on intensity curve derivative calculation.
4. Extracting intensity values for consonant and vowel segments based on the previous identification of events.

From a segmental point of view, and in order to obtain the values for consonant duration and intensity ratio, it was necessary to identify the C+V sequence on the spectrograph and run the corresponding script section to select the consonant under study. Thus, the first stage of the procedure consisted in viewing and editing the spectrographic image and running the corresponding script section to obtain the intensity derivative curve calculated by Praat. Praat text grid screens served to place rough boundaries for the consonant and the flanking vowel, which was based on visual observation of the spectrographic image, the acoustic waveform and the intensity derivative curve. Figure 2.3 shows the first stage of the analysis procedure, illustrating the screen display that included the following parts from top to bottom: waveform, spectrograph, consonant boundary tier, word tier, and intensity curve derivative.

Figure 2.1

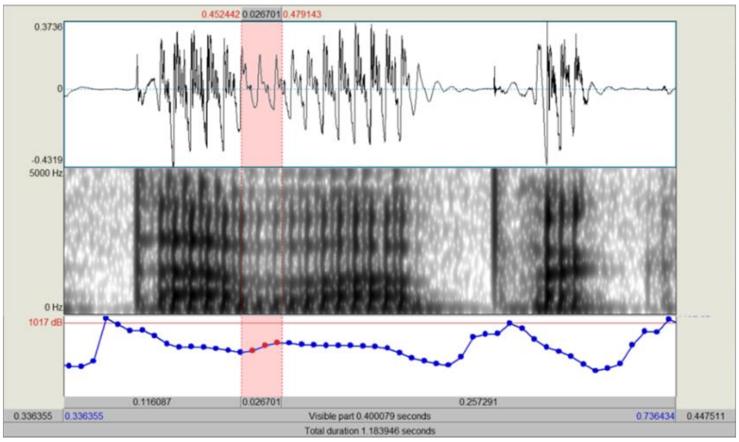
Observation of spectrographic image and boundary placement



After selecting rough time boundaries for consonant and vowels segments, the corresponding section of the Praat script was run to automatically obtain the exact selection of the consonantal segment. This was based on maximum and minimum peaks provided by the intensity derivative curve, which the routine took as reference points for consonant segmentation. Figure 2.4 shows the selection outcome provided by the Praat routine for /b/ in “tabapa” (fast), which can be visualized synchronously on the waveform, the corresponding spectrographic image, and the intensity derivative curve. At this stage, the Praat script also provided the exact three main time measurements in a table, which were saved in Excel documents for future processing and to calculate consonant duration. Vowel duration was not a relevant value, but the corresponding time boundary was considered to extract the intensity measurement to calculate the intensity ratio value.

Figure 2.2

Automatic segmentation for “tabapa” (fast)



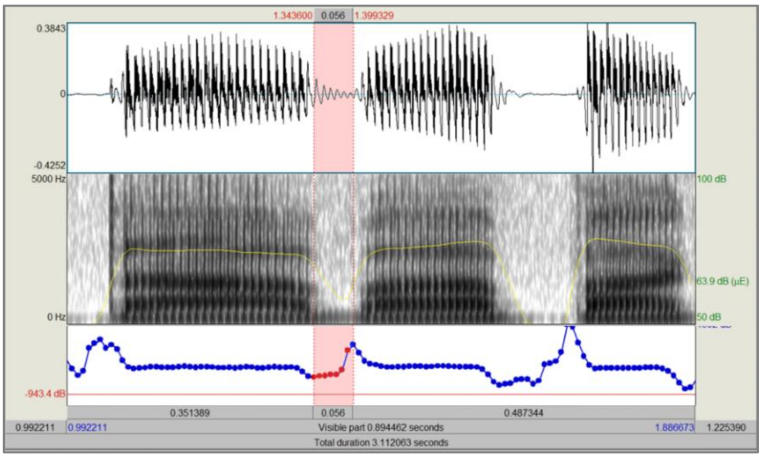
As shown in Figure 2.4, the simultaneous screen display of consonant segmentation based on intensity curve derivative peaks, the spectrograph and the sound wave allowed for further observation at this stage. It was considered necessary to check that the selection corresponded to the consonant for definitive segmentation. For more lenited realizations, where manual segmentation could result in inconsistent decisions, this procedure was adopted and the selection outcome was considered appropriate, which contributed to making the procedure as systematic as possible. However, for closer realizations, manual selection adjustments were occasionally used for accurate segmentation. This was also based on visual observation of formants, the existence of occlusion, fricative noise, or a vocalic transitional element, together with auditory perception.

In order to apply a consistent and systematic procedure, it was necessary to consider some issues that appeared as the analysis of tokens was carried out. In some closer realizations, derivative curve peaks showed events that could not be easily recognised as the beginning and/or end of the consonant element. This is the case of some VSCV sequences, especially in the case of fast speaking rates. That was probably due to aerodynamic phenomena occurring as undershooting takes place for a lenited consonant in a sequence of S+voiced plosive. Another segmentation issue appeared in the cases where a burst was present. The derivative curve showed a peak right before the burst, so bursts were left out of the segmentation process. This was also considered appropriate in most cases because it was consistent with the procedure applied for more open realizations. However, manual adjustments were considered necessary in a few cases where the derivative curve peak did not seem to correspond to the beginning of the following gesture.

Finally, after segmentation issues were carefully worked out and decisions were taken, the third stage of the procedure was carried out. This consisted in extracting intensity values corresponding to the selected consonant and vowel. In order to automate this process, the Praat script written for the experiment also included commands to extract the minimum intensity for the consonant and the maximum intensity for the vowel. These values were saved in an Excel file to calculate the intensity ratio value that would be used as the acoustic cue of consonant constriction. Figure 2.5 shows the automatic segmentation outcome for a close realization.

Figure 2.3

Automatic segmentation for "tabapa" (slow)



2.5 Data screening and statistics

In order to manage the data extracted in the acoustic analysis, the *Statistical Package for the Social Sciences (SPSS)* for Windows, version 23 (compatible with more recent updates), was used to perform all the statistical analyses reported in this work. After the acoustic analysis procedure was completed, a number of Excel data analysis files were created containing the raw measurements and the calculations corresponding to consonant duration and intensity ratio. All the resulting calculations for both dependent variables were collected in a new Excel file that would constitute the data template to be used to perform a general screening and raw observation of means, and the subsequent statistical analysis on SPSS.

Screening data at this stage consisted in calculating mean values and standard deviations on the Excel file for the two variables, in order to make some decisions concerning statistical analysis procedures. First, running some basic mean and standard deviation calculations on the master template file showed the existence of some potential outliers, since some values differed from the mean between two and three standard deviation units. Thus, the corresponding normality test was run on SPSS to check whether it was necessary to discard some data. In order to test normality, data were grouped by factors according to the comparisons that could be relevant in the subsequent statistical tests. Thus, data had to be grouped by rate, where values were expected to be significantly different. Another required group was context, since it included homorganic sequences for VLCV and VNCV, together with VOV, corresponding to voiceless plosives. These were expected to provide some extreme values that could be interpreted as outliers.

Normality tests and identification of outliers were based on Kolmogorov-Smirnov tests run on SPSS. In the outcome of this test, extreme values are identified and shown as outliers on boxplots. SPSS can identify two different types of outliers, based on two different inter-quartile range rule multipliers: 1.5 and 3.0. These are shown by circles and asterisks (respectively) on SPSS results, as displayed, for example, in Figure 2.6 for intensity ratio and the context*rate group. It has been argued (Hoalgin & Iglewicz, 1987) that 1.5 provides inaccurate results 50% of the time as those marked as circles may not be real outliers. So, for the purpose of this work, it was considered appropriate to focus on those values marked as asterisks. It was observed that very few values were considered extreme, and when this happened, it corresponded to those whose mean difference was closer to 3 times the standard deviation. According to these observations, only one extreme value was discarded for duration (slow rate), and three cases were discarded for intensity ratio (one for the fast rate and two for the slow rate). These tokens were replaced with the mean value of the remaining tokens. Table 2.3 shows the test values corresponding to the boxplot graph in Figure 2.6. Although according to significance results some cases could be interpreted as violating the normality, only the case marked as an asterisk in Figure 2.6 is considered (VLCV) a potential outlier.

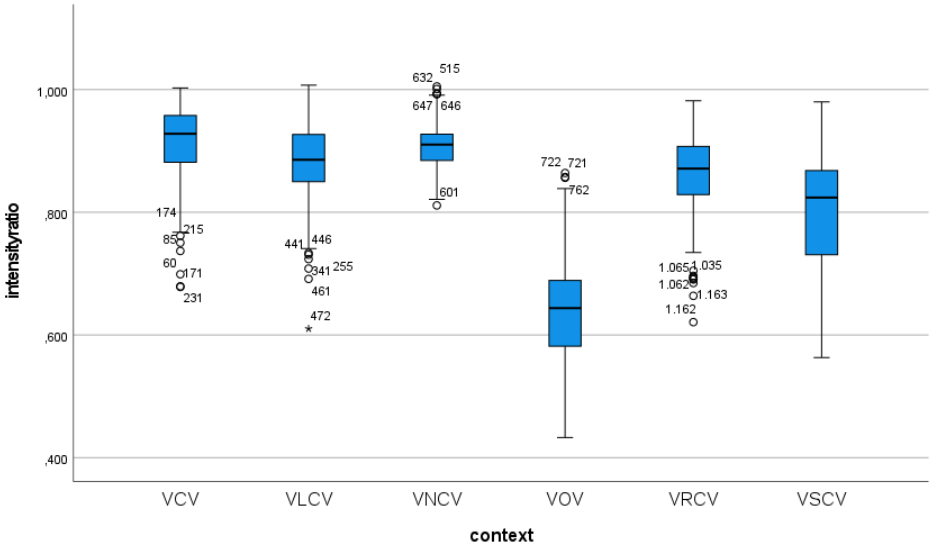
Table 2.3

*Results of Kolmogorov-Smirnov normality test for intensity ratio (context*rate–fast)*

		Kolmogorov-Smirnov		
Context		*Statistic*	*df*	*Sig.*
Intensity ratio	VCV	.119	240	<001
	VLCV	.084	180	.004
	VNCV	.068	240	.009
	VOV	.040	240	.200
	VRCV	.077	240	.001
	VSCV	.108	240	<001

Figure 2.4

*Kolmogorov-Smirnov test boxplots for context*rate for intensity ratio (slow)*



The first raw observation of data also showed duration and intensity ratio differences across the levels for the main factor in this study (rate) and across the levels of the rest of factors (context, point of articulation and vowel). For example, Table 2.4 and Table 2.5 show descriptive statistics results for the rate factor and provides a general view of potential significant differences between fast and slow rates. The data show mean values for consonant duration (expressed in milliseconds), while intensity ratio values correspond to the consonant-vowel ratio calculated as explained in this chapter, with values closer to 1 representing more lenited realizations. The inferential statistical analysis provide data for both main effects and factor interactions, in order to scrutinize the effect of speaking rate across the rest of independent variables.

Table 2.4

Duration mean values for fast and slow rates

		DURATION		
		MEAN	N	SD
RATE	FAST	38.811	1380	16.490
	SLOW	67.256	1380	30.675

Table 2.5

Intensity ratio mean values for fast and slow rates

		INT-R		
		MEAN	N	SD
RATE	FAST	.832	1380	.119
	SLOW	.756	1380	.151

Regarding statistical tests, previous studies on Spanish stop lenition commonly use repeated measures ANOVA analyses (Colantoni & Marinescu, 2010; Martínez & Regueira, 2008; Romero, 1995; Soler & Romero, 1999). However, some problematic issues have been reported to play a role in the interpretation of the results obtained from these tests (Max & Onghena, 1999), making the choice of appropriate statistical tests a crucial procedure decision. The main problems associated with repeated measures ANOVAs are related to violations of sphericity and data interdependence issues. As explained in Max & Onghena (1999), in the case of independent variables with three or more condition levels, the sphericity assumption guarantees that the variance of the differences between all combinations of levels of each independent variable are homogeneous, and it must be ensured that this assumption is not violated. ANOVAs do not account for this issue, which poses a problem in the interpretation of results. Another main issue is that data interdependence cannot be guaranteed in ANOVA tests when data includes various trials by the same subject. While data units (trials) are considered independent, error effects are not independent and are computed across individual data units.

In order to avoid these problems, a linear mixed-effects model analysis has been chosen for inferential statistics. As explained in Chapter 3, interdependence issues arising from replication and subject can be handled by mixed-model analysis tests effectively by separating random effects and fixed effects appropriately. In addition, the model also handles missing data imbalances effectively (Winter, 2013).

Chapter 3 Results

The present chapter reports on the results obtained in the analyses performed in this study, which include statistical data and qualitative observations (as explained in Chapter 1). Statistical data will be the focus of this chapter in order to observe the effects of the selected factors on dependent variables and provide general support to the main hypothesis of this work, i.e., the determining role of speaking rate. Thus, all results will be organized around the statistical analysis for this factor, and the analysis will focus on the data obtained for duration and intensity ratio measurements as a function of rate, as well as other observation facts about the behaviour of these variables under the selected conditions. Later, these data will also be examined in the light of the corresponding qualitative description to categorize the observed realizations and the differences among them. Thus, selected qualitative observations, based on the spectrographic images obtained in the acoustic analysis, will provide more evidence of the behaviour of variables and the patterns obtained.

As explained in Chapter 1, the main hypothesis in this study states that stop lenition in Spanish involves decreased gestural magnitude whereby the target realization is undershot and so is not completely achieved due to timing constraints. This reduction can be observed through the selected acoustic cues that constitute the dependent variables in this analysis, that is, indicating consonant constriction degree and consonant length, as explained in detail in Chapter 2. The statistical results obtained from the tests performed show how the dependent variables behave under the given conditions. These tests are expected to yield a significant difference between the two different speaking rates in resulting realizations that are predicted to exhibit reduced constriction and reduced duration, which would go along in this phenomenon. As shown in previous studies and hypothesized in the present work, variability and various consonant constriction degrees are also expected, so tests are run to look into possible patterns for constriction degrees and the differences exhibited by the variables under the given conditions.

Although this study mainly focuses on the effect of speaking rate and how it determines variability in lenited realizations, the multi-dimensionality of Spanish stop lenition calls for the analysis of other factors that have been reported to play some role in the occurrence of this phenomenon. In addition to the main factor under study, i.e., rate, voiced stop lenition in Castilian Spanish is also conditioned (to a greater or lesser extent) by context (flanking segments), point of articulation (PoA) and vowel, and their effects will also be reported when relevant, especially in their interaction with speaking rate. Table 3.1 shows all the factors and variables included in the statistical analysis.

Table 3.1

Factors included in the statistical analysis

	(PoA)					
	Labial		Dental		Velar	
	(VOWEL)		**(VOWEL)**		**(VOWEL)**	
CONTEXT	/a/	/u/	/a/	/u/	/a/	/u/
Intervocalic (VCV)	/aba/	/ubu/	/ada/	/udu/	/aga/	/ugu/
After lateral (VLCV)	/alba/	/ulbu/	/alda/	/uldu/	/alga/	/ulgu/
After nasal (VNCV)	/amba/	/umbu/	/anda/	/undu/	/anga/	/ungu/
After rhotic (VRCV)	/arba/	/urbu/	/arda/	/urdu/	/arga/	/urgu/
After fricative (VSCV)	/asba/	/usbu/	/asda/	/usdu/	/asga/	/usgu/
Voiceless stop (VOV)	/apa/	/upu/	/ata/	/utu/	/aka/	/uku/
REPETITION (10 repetitions)						
SUBJECT (4 subjects)						
RATE (2 rates)						

In order to focus on the relevant information to test the stated hypotheses, the exposition of results is organized according to the observed effects of speaking rate on the dependent variables selected (consonant duration and intensity ratio), which will constitute the main subsections in the present chapter. However, some preliminary results and observations that determine the subsequent analysis of speaking rate effects are reported in section 3.1 and section 3.2. First of all, section 3.1 reports on the results of some preliminary tests that were carried out to illustrate the random nature of subject and replication in this study. The main purpose of these observations is to show how pseudoreplication effects do not play a role in the statistical results in this work, and how misleading results are avoided (as explained in Winter, 2011).

After the treatment of the repetition factor is explained, in section 3.2 results focus on the observations of main effects for all the tested factors. These results show how each factor under study conditions consonant duration and intensity ratio, so relevant data are selected to show the effect of rate, context, point of articulation and vowel separately. These data include all other conditions for each factor, which will require more detailed analyses to provide the evidence that can fully support the stated hypotheses. However, although they can be considered a part of preliminary observations, both the analysis of the repetition factor and main effects data provide a general idea of effect robustness that guides more detailed observations in the rest of the present chapter.

After showing the results obtained in these first tests, the effects of speaking rate are analysed in detail in order to focus on the data that will support the main hypotheses in this study. To that aim, section 3.3 looks into the effect of rate on consonant duration, while section 3.4 concentrates on the effects of speaking rate on intensity ratio. These analyses will allow to observe the corresponding relevance of effects and later describe the stricture types obtained accordingly. These main sections will be structured into parallel subsections to show the relevant results of the interaction of factors. The first subsection will highlight the interactions observed between rate and context. Similarly, the second and third subsections will focus on the interactions observed between rate and the rest of independent variables (point of articulation and vowel), respectively, as it is observed that rate also determines some of the resulting variability.

For both of the dependent variables analysed, the results of the effect of factors will be reported in tables and figures for ease of presentation and clarity. Tables provide the outcome of the comparison tests performed in the mixed-models analysis run on the SPSS Statistical Package, and show data and detail as required to illustrate different facts: norms, trends, deviations, and comparisons. Three different tables are used to display these results most appropriately and provide support for the observed facts in the behaviour of dependent variables. The first type of table shows the results of fixed effects tests, which provide general information about potentially important predictors of the dependent variable, and help to identify which factors need to be further explored. The second type displays the results of univariate tests to report on the significance of a single effect for other given conditions by indicating whether the analysed means are different within groups. The third type of table shows the detail of pairwise comparisons to examine how the effect of a given factor (shown in univariate tests) is specified, especially for factors that include more than two levels.

These results are all expressed in terms of selected values for the different types of tables and for both main effects and interaction tests. *F*-values and *P*-values are used to express significance, which is based on the Bonferroni tests performed in the mixed-models analysis. Tests are judged significant if the probability level is .01 (i.e. 1%) or smaller ($p < 0.1$), and *P* values displayed in SPSS output as .000 are expressed as <.001 in the tables, while in all other cases, the actual *P* value is provided. "Greater than (>)"

and "less than (<)" symbols alone are used in some cases for values above and below significance level (.01) respectively in pairwise comparisons to avoid unnecessary load in tables. Other values are included in tables and figures when relevant, i.e., mean values (*M*), standard deviation values (*SD*) and degrees of freedom (*df*).

Figures, in turn, consist of column graphs that plot the mean values for comparisons between the specific factor levels. These differences are mainly focused on the slow and fast rates, as speaking rate is considered the most relevant factor in this study, but they also refer to the rest of factor levels to illustrate differences when necessary. These mean values correspond to either duration or intensity ratio measurements as indicated, and they show two relevant facts: first, which of the levels exhibits higher or lower values, and second, which comparisons yield greater or smaller differences. Mean values for duration and intensity ratio are shown in the *y*-axis. They are expressed in milliseconds (ms) for consonant duration results, whereas for intensity ratio, a consonant-vowel ratio value is shown that results from dividing consonant intensity minimum by vowel intensity maximum (as described in Chapter 2). Standard error bars, indicating variability, are also shown above the bars.

3.1 The random factor and replication

As explained in Chapter 2, the mixed-models analysis allows to combine random factors and fixed factors in order to resolve non-independencies in the selected data (as explained in Winter, 2013). By including a random "subject", this model assumes that there are multiple responses per subject, and it characterizes variation that may be due to individual differences. If the model can account for variation by subject, it can be assumed that the choice of specific subjects does not systematically condition statistical results and it is possible to generalize over the idiosyncrasies of individual subjects.

Similarly, non-independency problems can also be due to by-item variation when multiple repetitions by the same subject are used. In these cases, pseudoreplication effects may play a role (Winter, 2011) and must be accounted for in the model. As explained in Chapter 2, in order to test the potential effect of replication, the repetition factor has been included in the analysis in order to test its main effect as well as two-way, three-way and multiple interactions. The purpose of this initial analysis is to show the random nature of repetitions and to discard them as a factor to focus on the relevant factors under study.

The results of the tests for the effect of repetitions show that duration and intensity ratio are not significantly affected by the repetition factor. In the case of duration, tests for main effects yielded no significant differences between compared means for the 10 repetitions. In the same line, fixed effects tests performed for intensity ratio showed that differences across repetitions are not significant either. In order to illustrate the results of tests including the repetition factor, the three types of tables presented above are used as appropriate to show the required detail. Since interest mainly lies in significance data for repetition effects, bar graphs are not considered relevant, and are not used in this section. Table 3.2 shows the results of fixed effects for main effects of the repetition factor.

Table 3.2

Fixed effects test results for main effect of repetition for duration and intensity ratio

MAIN EFFECT	DEPENDENT VARIABLES	*df*	*F*	*P*
Repetition	DURATION	9,2755.993	0.565	.827
	INTENSITY RATIO	9,2756.034	1.028	.415

Although the results for the effect of repetitions show that differences are not significant as a main effect, the effect of this factor is further explored in the present analysis. Interaction analyses were run in two-way, three-way and multiple modes, including the repetition factor with the rate factor in different combinations: rate*repetition for two-way interaction, rate*context*repetition, rate*PoA*repetition, and rate*vowel*repetition for three-way tests, and rate*vowel*PoA*context*repetition for multiple-interaction analyses. Table 3.3 shows the results of fixed effects for consonant duration and intensity ratio in all the interactions examined. The data show that all these interactions are significant (p<.001) or very close to significance (p=.002 for intensity ratio in the case of rate*PoA*repetition). Thus, the details of these results are explored throughout this section with the main purpose of discarding the non-significant effect of the repetition factor.

Table 3.3

Fixed effects test results for interactions with repetition for duration and intensity ratio

INTERACTION	DEPENDENT VARIABLES	*df*	*F*	*P*
rate * repetition	DURATION	19,2756.001	170.397	<.001
	INTENSITY RATIO	19,2756.007	34.200	<.001
rate * context * repetition	DURATION	100,2756.027	63.666	<.001
	INTENSITY RATIO	100,2756.051	51.429	<.001
rate * poa * repetition	DURATION	40,2756.001	4.699	<.001
	INTENSITY RATIO	40,2756.007	1.786	.002
rate * vowel * repetition	DURATION	20,2756.001	16.858	<.001
	INTENSITY RATIO	20,2756.007	6.000	<.001
rate * vowel * poa * context * repetition	DURATION	719,2756.002	20.917	<.001
	INTENSITY RATIO	719,2756.02	11.850	<.001

Since fixed effects tests yielded significant results for most factor interactions including repetition (as shown in Table 3.3), univariate and pairwise comparisons tests were carried out to examine this significance. Detail of results is reported for the effect of the repetition factor and the rate factor, in order to observe how their roles are different in the analysed interactions. Firstly, for the two-way interaction (repetition*rate), Table 3.4[4] shows the results of univariate tests for the effect of repetition by rate for both variables. These results show non-significance for the effect of repetition across the two rates, which is further explored by means of pairwise comparisons.

Table 3.4

Results of univariate tests for the effect of repetition on consonant duration and intensity ratio across rate

	DURATION			INT-R		
Repetition*rate	*df*	*F*	*P*	*df*	*F*	*P*
FAST	9, 2756.001	.715	.696	9, 2756.007	1.508	.139
SLOW	9, 2756.001	.811	.606	9, 2756.007	.738	.674

In the same line, the results of pairwise comparisons for the repetition*rate interaction show that the repetition factor does not have a significant effect on duration

[4] "INT-R" (short for "intensity ratio" is used as a heading in tables to avoid table load

or intensity ratio in any of the comparisons. Table 3.5 and Table 3.6 show the corresponding detail of comparisons for the fast rate and the slow rate, and they are only shown for the two-way interaction to illustrate how differences remain non-significant in all the comparisons. The data shown include the mean values for each repetition, standard deviation, and significance corresponding to pairwise comparisons between repetitions. In those cases where the comparisons are not significant, differences between the values are expressed as “>” or “<” for simplicity. These comparisons across rates include the rest of conditions globally, but general results show a clear trend for us to assume that pseudoreplication effects do not play a role in this study. For the rest of the interactions analysed, univariate tests alone are shown to illustrate de non-significant effect of the repetition factor.

Table 3.5

Pairwise comparisons for the effect of repetition on consonant duration across rate

			DURATION												DURATION									
Repetition			1	2	3	4	5	6	7	8	9	10			1	2	3	4	5	6	7	8	9	10
Rate			FAST												SLOW									
	M	*SD*	*mean comparisons (p)*										*M*	*SD*	*mean comparisons (p)*									
1	39.342	17.780		>	>	>	>	>	>	>	>	>	66.538	30.907		>	>	>	>	>	>	>	>	>
2	40.365	17.301			>	>	>	>	>	>	>	>	68.646	29.526			>	>	>	>	>	>	>	>
3	38.921	15.592				>	>	>	>	>	>	>	68.512	33.865				>	>	>	>	>	>	>
4	39.551	16.456					>	>	>	>	>	>	67.560	32.563					>	>	>	>	>	>
5	38.931	15.786						>	>	>	>	>	65.917	28.393						>	>	>	>	>
6	39.395	17.852							>	>	>	>	65.622	29.185							>	>	>	>
7	37.372	15.729								>	>	>	67.963	29.395								>	>	>
8	38.227	16.691									>	>	67.446	31.109									>	>
9	37.871	15.644										>	67.392	30.766										>
10	38.143	16.173											66.970	31.487										

Table 3.6

Pairwise comparisons for the effect of repetition on intensity ratio across rate

			INT-R												INT-R									
Repetition			1	2	3	4	5	6	7	8	9	10			1	2	3	4	5	6	7	8	9	10
Rate			FAST												SLOW									
	M	*SD*	*mean comparisons (p)*										*M*	*SD*	*mean comparisons (p)*									
1	.822	.122		>	>	>	>	>	>	>	>	>	.751	.157		>	>	>	>	>	>	>	>	>
2	.823	.122			>	>	>	>	>	>	>	>	.767	.141			>	>	>	>	>	>	>	>
3	.837	.109				>	>	>	>	>	>	>	.751	.148				>	>	>	>	>	>	>
4	.831	.118					>	>	>	>	>	>	.761	.149					>	>	>	>	>	>
5	.821	.127						>	>	>	>	>	.750	.151						>	>	>	>	>
6	.834	.120							>	>	>	>	.754	.148							>	>	>	>
7	.848	.117								>	>	>	.757	.148								>	>	>
8	.837	.119									>	>	.760	.159									>	>
9	.834	.122										>	.756	.156										>
10	.836	.119											.749	.159										

However, the details of the analysis outcome deserve further comments since the two-way interaction test yielded significant differences for fixed effects and for both dependent variables. Univariate tests also show that this significance is caused by the effect of the rate factor, and the differences between the corresponding means for consonant duration and intensity ratio are significant across rates in all cases. This indicates the powerful effect of the rate factor, as opposed to the effect of repetition at this stage. The role of rate will be explored in more detail in section 3.3 and section 3.4 in this chapter. Table 3.7 displays the results of univariate tests for individual repetitions across the fast and slow rates for both dependent variables, indicating the significant differences in all the cases.

Table 3.7

Results of univariate tests for the effect of rate across repetition for duration and intensity ratio

DURATION				INT-R			
Rate*repetition	*df*	*F*	*P*	Rate*repetition	*df*	*F*	*P*
1	1,2756.001	291.189	<.001	1	1,2756.007	53.748	<.001
2	1,2756.001	316.677	<.001	2	1,2756.007	33.138	<.001
3	1,2756.001	349.481	<.001	3	1,2756.007	79.209	<.001
4	1,2756.001	310.925	<.001	4	1,2756.007	52.227	<.001
5	1,2756.001	292.092	<.001	5	1,2756.007	55.388	<.001
6	1,2756.001	278.428	<.001	6	1,2756.007	68.991	<.001
7	1,2756.001	373.590	<.001	7	1,2756.007	87.131	<.001
8	1,2756.001	340.303	<.001	8	1,2756.007	62.647	<.001
9	1,2756.001	347.545	<.001	9	1,2756.007	65.441	<.001
10	1,2756.001	330.042	<.001	10	1,2756.007	81.800	<.001

Similarly, three-way mixed effect tests (rate*context*repetition, rate*PoA*repetition, and rate*vowel*repetition) and multiple interaction tests (rate*vowel*PoA*context*repetition) yielded significant results, which again are further explored to discard the effect of repetition and observe the strong role of rate in these interactions. The rest of factors intervening in these three-way tests (context, vowel or PoA) could also play a role in the observed significance, but are not reported here as the strength of their effect as individual factors is not relevant for the purpose of observing the results for the repetition factor.

Univariate tests for three-way and multiple interactions yielded non-significant results for the effect of repetition. This result can be seen, in the first place, in the rate*context*repetition interaction, where the effect of the repetition factor is reported as non-significant when repetitions are compared by context in each rate. Table 3.8 displays the results of univariate tests for the effect of repetition across contexts. The data show that the differences between the 10 repetitions for each context and rate are not significant in any of the comparisons.

Table 3.8

Results of univariate tests for the effect of repetition across rate and context for duration and intensity ratio

	DURATION					INT-R				
Repetition*rate		FAST		SLOW			FAST		SLOW	
Context	*df*	*F*	*P*	*F*	*P*	*df*	*F*	*P*	*F*	*P*
VCV	9, 2756.001	.202	.994	1.401	.182	9, 2756.007	.327	.967	1.218	.279
VLCV	9, 2756.001	.455	.905	.370	.950	9, 2756.007	.375	.948	.358	.955
VNCV	9, 2756.001	.088	1.000	.353	.957	9, 2756.007	.122	.999	.340	.962
VRCV	9, 2756.001	.481	.888	.394	.939	9, 2756.007	1.000	.437	1.516	.136
VSCV	9, 2756.001	.301	.975	.431	.919	9, 2756.007	1.477	.150	2.091	.027
VOV	9, 2756.001	.284	.979	1.286	.239	9, 2756.007	.784	.631	.476	.892

As it was reported for the two-way interaction (repetition*rate), in the rate*context*repetition interaction, individual comparisons appear as significant again when fast and slow rates are the focus of the comparison. Although this effect is clearly strong, some differences between the fast and the slow rate appear as non-significant when results are grouped by repetition. Table 3.9a shows how the effect of rate is significant in all comparisons for consonant duration, except for VNCV. This fact can be interpreted as an effect of the number of cases analysed for each repetition in this interaction (24 vs 24). But it can also be assumed that comparisons involving nasal contexts could yield less significance due to a stronger effect of coarticulation, as nasalization is extended through the realization of the complete sequence, resulting in similar consonant durations. This result could be different from the resulting significance in a more general analysis without repetition sorting, which will be described in detail in sections 3.3 and 3.4 below.

Table 3.9a

Results of univariate tests for the effect of rate across context and repetition for duration

		DURATION												
Rate*context		VCV		VLCV		VNCV		VRCV		VSCV		VOV	
Repetition	*df*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
1	1, 2756.001	57.360	<.001	14.537	<.001	2.455	.117	64.101	<.001	48.330	<.001	208.592	<.001
2	1, 2756.001	85.355	<.001	19.360	<.001	5.789	.016	48.343	<.001	52.988	<.001	191.167	<.001
3	1, 2756.001	67.142	<.001	27.672	<.001	1.121	.290	68.784	<.001	49.864	<.001	267.791	<.001
4	1, 2756.001	80.616	<.001	19.718	<.001	1.550	.213	48.320	<.001	56.507	<.001	211.882	<.001
5	1, 2756.001	62.527	<.001	26.663	<.001	2.599	.107	60.226	<.001	48.379	<.001	164.166	<.001
6	1, 2756.001	50.254	<.001	32.271	<.001	5.130	.024	52.554	<.001	37.639	<.001	161.153	<.001
7	1, 2756.001	102.287	<.001	29.811	<.001	2.521	.112	73.499	<.001	64.645	<.001	196.638	<.001
8	1, 2756.001	94.100	<.001	25.867	<.001	1.716	.190	62.733	<.001	54.485	<.001	202.771	<.001
9	1, 2756.001	82.708	<.001	26.856	<.001	4.773	.029	67.087	<.001	53.922	<.001	199.354	<.001
10	1, 2756.001	89.488	<.001	22.428	<.001	2.780	.096	64.306	<.001	54.645	<.001	188.037	<.001

In the same three-way comparison (rate*context*repetition interaction), the results for intensity ratio are quite solid for the effect of rate. In fast vs slow comparisons by context and repetition, the test yielded significant results in many cases. In the case of flanking nasal and flanking lateral (VNCV and VLCV contexts), the differences are mostly not significant. This result does not coincide completely with duration results, where comparisons in the VLCV were also significant. For the purpose of interpreting these results, again, it is assumed that coarticulation effects with the nasal consonant play an important role in the sonority (thus, intensity ratio) of /b/ /d/ and /g/, besides the small number of cases being compared in this interaction by repetition. Table 3.9b shows the results of univariate tests, where still an extensive significance can be observed for the effect of rate.

Table 3.9b

Results of univariate tests for the effect of rate across context and repetition for intensity ratio

		INT-R											
Rate*context		VCV		VLCV		VNCV		VRCV		VSCV		VOV	
Repetition	*df*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
1	1, 2756.007	9.627	.002	2.009	.156	2.257	.133	9.552	.002	12.970	<.001	30.431	<.001
2	1, 2756.007	11.890	.001	3.328	.068	4.592	.032	1.267	.261	1.058	.304	21.486	<.001
3	1, 2756.007	17.334	<.001	8.619	.003	2.552	.110	7.604	.006	20.786	<.001	35.168	<.001
4	1, 2756.007	8.032	.005	5.624	.018	2.263	.133	7.546	.006	17.327	<.001	17.647	<.001
5	1, 2756.007	9.269	.002	7.373	.007	1.487	.223	16.822	<.001	13.467	<.001	12.665	<.001
6	1, 2756.007	19.608	<.001	6.662	.010	3.319	.069	12.047	.001	12.729	<.001	21.476	<.001
7	1, 2756.007	35.790	<.001	4.225	.040	3.369	.067	13.600	<.001	18.381	<.001	28.348	<.001
8	1, 2756.007	31.027	<.001	4.234	.040	1.891	.169	2.731	.099	10.780	.001	32.054	<.001
9	1, 2756.007	20.330	<.001	8.885	.003	1.572	.210	8.504	.004	12.572	<.001	22.014	<.001
10	1, 2756.007	17.322	<.001	8.820	.003	2.113	.146	9.857	.002	25.482	<.001	30.565	<.001

In the rest of three-way interactions analysed, other comparisons including the repetition factor help to observe the non-significant effect of repetitions. In the rate*repetition*PoA interaction, which appears as significant for fixed effects, it is also necessary to look into the effect of each factor to check that repetitions are not the source of this significance. Indeed, when the ten repetitions are compared by rate and point of articulation, differences are not significant for any of the dependent variables. Table 3.10 displays *F* and *P* values for the effect of repetitions for each rate and across the three points of articulation for the two dependent variables. The differences between means in pairwise comparisons for the 10 repetitions are not significant in any case. This result is the same as in the previously analysed three-way interaction, and calls for further observation to examine the source of the significance displayed for fixed-effects results.

Table 3.10

Results of univariate tests for the effect of repetition across rate and PoA for duration and intensity ratio

		DURATION				INT-R				
Repetition*rate		FAST		SLOW			FAST		SLOW	
PoA	*df*	*F*	*P*	*F*	*P*	*df*	*F*	*P*	*F*	*P*
Dental	9, 2756.001	.536	.850	.626	.775	9, 2756.007	.546	.841	.839	.580
Labial	9, 2756.001	.580	.815	.921	.505	9, 2756.007	1.460	.157	.575	.819
Velar	9, 2756.001	.581	.814	1.053	.395	9, 2756.007	.610	.790	.601	.797

According to these results shown in univariate tests, the significance showed in fixed effect tests for this three-way interaction is not based on the repetition factor, but on the effect of rate and, to a lesser extent, the effect of point of articulation. Like in other interactions, when fast and slow rates are compared across other factors, the differences are mostly significant. Table 3.11a displays the results of univariate tests for the effect of rate across PoA and repetitions for duration, and they show that differences are all significant. However, Table 3.11b shows that in the case of intensity ratio, differences for repetition 2 and for /g/ are not significant as a function of rate, although values are close to the significance established.

Table 3.11a

Results of univariate tests for the effect of rate across repetition and PoA for duration

		DURATION					
Rate*PoA		DENTAL		LABIAL		VELAR	
Repetition	*df*	*F*	*P*	*F*	*P*	*F*	*P*
1	1,2756.001	124.394	<.001	64.192	<.001	110.342	<.001
2	1,2756.001	107.051	<.001	121.304	<.001	91.785	<.001
3	1,2756.001	121.894	<.001	86.160	<.001	148.379	<.001
4	1,2756.001	126.737	<.001	79.333	<.001	110.120	<.001
5	1,2756.001	142.415	<.001	65.166	<.001	94.269	<.001
6	1,2756.001	121.221	<.001	78.315	<.001	83.768	<.001
7	1,2756.001	135.963	<.001	117.681	<.001	123.164	<.001
8	1,2756.001	157.209	<.001	86.865	<.001	104.362	<.001
9	1,2756.001	143.031	<.001	106.536	<.001	102.669	<.001
10	1,2756.001	142.316	<.001	96.091	<.001	97.116	<.001

Table 3.11b

Results of univariate tests for the effect of rate across repetition and PoA for intensity ratio

		INT-R					
Rate*PoA		DENTAL		LABIAL		VELAR	
Repetition		*F*	*P*	*F*	*P*	*F*	*P*
1	1,2756.007	32.422	<.001	6.819	.009	19.727	<.001
2	1,2756.007	9.088	.003	15.923	<.001	9.024	.003
3	1,2756.007	31.290	<.001	21.891	<.001	27.058	<.001
4	1,2756.007	13.736	<.001	23.008	<.001	16.504	<.001
5	1,2756.007	20.090	<.001	13.006	<.001	23.535	<.001
6	1,2756.007	18.241	<.001	29.165	<.001	22.757	<.001
7	1,2756.007	29.621	<.001	21.068	<.001	38.405	<.001
8	1,2756.007	16.032	<.001	20.492	<.001	27.363	<.001
9	1,2756.007	17.411	<.001	16.902	<.001	33.424	<.001
10	1,2756.007	25.208	<.001	27.698	<.001	29.613	<.001

The last three-way interaction analysed, rate*repetition*vowel, also deserves attention to discard the effect of repetition and inspect the strength of the effect of the factors under study. This interaction also appears as significant for fixed effects in the statistical analysis (see Table 3.3), and the effects of each factor involved need to be worked out. The repetition factor across rate and vowel appears as non-significant again for both dependent variables. Table 3.12 shows how consonant durations are not significantly different when repetitions are compared across the fast and slow rates and vowels (/a/ and /u/). The same result can be observed for intensity ratio values, which adds to the results that have been observed for the effect of the repetition factor throughout this section. However, the rate*repetition*vowel interaction still appears as significant due to the role of the rate and vowel conditions. Univariate tests for the effect of rate are displayed in Table 3.13, where it can be observed that rate is significant in all cases, both for duration and intensity ratio. This contributes to assuming that speaking rate plays a relevant role when included in any comparisons.

Table 3.12

Results of univariate tests for the effect of repetition across rate and vowel for duration and intensity ratio

	DURATION					INT-R				
Repetition*rate		FAST		SLOW			FAST		SLOW	
Vowel	*df*	*F*	*P*	*F*	*P*	*df*	*F*	*P*	*F*	*P*
a	9, 2756.001	.520	.861	.538	.848	9, 2756.007	.546	.841	.839	.580
u	9, 2756.001	.978	.456	.842	.578	9, 2756.007	1.460	.157	.575	.819

Table 3.13

Results of univariate tests for the effect of rate across repetition and vowel for duration and intensity ratio

	DURATION					INT-R				
Rate*Vowel		a		u			a		u	
Repetition	*df*	*F*	*P*	*F*	*P*	*df*	*F*	*P*	*F*	*P*
1	1,2756.001	155.628	<.001	137.517	<.001	1,2756.007	27.426	<.001	26.634	<.001
2	1,2756.001	144.051	<.001	175.210	<.001	1,2756.007	14.168	<.001	19.363	<.001
3	1,2756.001	157.175	<.001	195.354	<.001	1,2756.007	33.382	<.001	46.852	<.001
4	1,2756.001	136.463	<.001	177.604	<.001	1,2756.007	20.711	<.001	32.476	<.001
5	1,2756.001	136.010	<.001	158.181	<.001	1,2756.007	29.706	<.001	26.060	<.001
6	1,2756.001	114.546	<.001	168.038	<.001	1,2756.007	20.846	<.001	52.050	<.001
7	1,2756.001	161.591	<.001	216.128	<.001	1,2756.007	35.725	<.001	52.733	<.001
8	1,2756.001	152.288	<.001	191.071	<.001	1,2756.007	24.863	<.001	38.929	<.001
9	1,2756.001	151.492	<.001	199.716	<.001	1,2756.007	27.448	<.001	38.864	<.001
10	1,2756.001	142.857	<.001	190.817	<.001	1,2756.007	28.443	<.001	56.163	<.001

Finally, multiple-interaction tests with the repetition factor involve the most specific analysis in this study, and although the interaction is reported as significant for fixed effects (See Table 3.3), it reveals less significance for the effect of all conditions in general. The results of the multiple-interaction test including repetition yields some interesting results besides more evidence of the random nature of repetition. Once more, the effect of repetition is revealed as non-significant in all the cases and comparisons. Table 3.14a shows the results of univariate tests corresponding to the effect of repetition across rate, vowel, point of articulation and context for consonant duration. All comparisons are non-significant, except the case of compared repetitions for the voiceless counterpart and u (/uku/) in the slow rate. Considering the small number of cases compared in these tests (4 for each repetition), the results can still be considered robust for this effect in these specific comparisons.

Table 3.14a

Results of univariate tests for the effect of repetition across rate, PoA and vowel for duration

Repetition* rate*vowel* PoA		DURATION												
		/a/							/u/					
			/d/		/b/		/g/		/d/		/b/		/g/	
Context	Rate	*df*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
VCV	F	9, 2755.999	.330	>	.345	>	.239	>	.294	>	.393	>	.349	>
VLCV		9, 2755.996	.225	>	.171	>	.317	>	.380	>	1.309	>	1.210	>
VNCV		9, 2755.999	.064	>	.048	>	.070	>	.051	>	.272	>	.124	>
VRCV		9, 2755.999	.386	>	.734	>	.112	>	1.348	>	1.033	>	.474	>
VSCV		9, 2755.999	.317	>	.221	>	.186	>	.373	>	.372	>	.702	>
VOV		9, 2755.999	.721	>	.549	>	.450	>	.508	>	1.627	>	1.583	>
VCV	S	9, 2755.999	.830	>	.687	>	.538	>	.685	>	1.337	>	1.430	>
VLCV		9, 2755.996	.450	>	.822	>	.454	>	1.189	>	.773	>	1.530	>
VNCV		9, 2755.999	.052	>	.586	>	.070	>	.633	>	.844	>	.301	>
VRCV		9, 2755.999	2.341	>	.382	>	.616	>	.939	>	1.102	>	2.192	>
VSCV		9, 2755.999	1.257	>	.735	>	1.536	>	.932	>	2.269	>	.906	>
VOV		9, 2755.999	.923	>	.811	>	1.238	>	1.288	>	.127	>	5.464	<.001

The non-significant effect of repetitions is maintained in multiple interaction for intensity ratio. Table 3.14b shows univariate tests for this effect, where some minor variability can be observed. Although the results indicate that the effect is again mainly non-significant, it appears as significant in some pairwise comparisons when few cases are the focus of the comparison. Indeed, when we explore the effect of the rest of factors in multiple interaction, more variability can be observed, as effects are weaker as a general trend. Thus, the resulting non-significant effect of repetitions can be considered quite strong by comparison.

Table 3.14b

Results of univariate tests for the effect of repetition across rate, PoA and vowel for intensity ratio

Repetition* rate*vowel* PoA			INT-R											
			/a/						/u/					
			/d/		/b/		/g/		/d/		/b/		/g/	
Context	Rate	*df*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
VCV	F	9, 2756.015	.311	>	.386	>	.442	>	.107	>	.272	>	.718	>
VLCV		9, 2756.015	.303	>	.345	>	.123	>	.211	>	.988	>	1.114	>
VNCV		9, 2756.015	.105	>	.063	>	.096	>	.190	>	.217	>	.301	>
VRCV		9, 2756.015	.145	>	1.171	>	.237	>	1.420	>	.585	>	.922	>
VSCV		9, 2756.015	.765	>	.948	>	.797	>	1.423	>	.854	>	.875	>
VOV		9, 2756.015	1.143	>	.288	>	.146	>	.833	>	3.228	.001	.823	>
VCV	S	9, 2756.015	.496	>	1.665	>	.951	>	2.222	>	1.522	>	2.757	>
VLCV		9, 2756.015	.209	>	.745	>	1.327	>	.317	>	.830	>	2.012	>
VNCV		9, 2756.015	.085	>	.495	>	.337	>	.186	>	.055	>	.474	>
VRCV		9, 2756.015	1.211	>	.996	>	2.868	>	1.192	>	1.426	>	2.889	>
VSCV		9, 2756.015	3.021	.001	1.457	>	1.021	>	1.384	>	3.559	<.001	1.672	>
VOV		9, 2756.015	.498	>	.990	>	.426	>	.185	>	.375	>	.606	>

Similarly, in multiple interaction with the repetition factor, the effect of rate loses some significance in comparison with two-way and three-way interactions. In order to illustrate this variability, and to avoid a very complicated visual, Table 3.15a and Table 3.15b show how rate conditions consonant duration and intensity ratio by vowel (/a/), point of articulation (dental), contexts and repetition. Table 15a shows how rate still affects consonant duration quite significantly for /d/, but it is less relevant in comparisons for /b/ and /g/. If we look at the effect of rate under the same conditions in multiple interaction for intensity ratio, results show a much weaker effect. This is illustrated in Table 3.15b, which displays significance only in comparisons involving some contexts and apparently quite randomly: flanking vowel (VCV), flanking fricative (VSCV) and voiceless plosive (/ata/). Further detail of significance for multiple interactions is not considered relevant as evidence of the effect of repetition or the effect of time.

Table 3.15a

Results of univariate tests for the effect of rate, across PoA (dental), vowel (/a/) and repetition for duration

Rate* vowel*PoA *context	DURATION												
	/a/												
	DENTAL												
		VCV		VLCV		VNCV		VRCV		VSCV		VOV	
Repetition	*df*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
1	1, 2755.999	33.228	<.001	2.426	>	.089	>	31.491	<.001	18.745	<.001	59.794	<.001
2	1, 2755.999	29.187	<.001	2.115	>	.352	>	16.736	<.001	15.897	<.001	44.391	<.001
3	1, 2755.999	17.831	<.001	.726	>	.017	>	35.675	<.001	16.867	<.001	45.206	<.001
4	1, 2755.999	33.884	<.001	1.783	>	.110	>	28.561	<.001	16.947	<.001	71.604	<.001
5	1, 2755.999	33.196	<.001	3.206	>	.132	>	32.123	<.001	31.673	<.001	51.818	<.001
6	1, 2755.999	17.045	<.001	2.026	>	.135	>	8.187	>	8.553	>	59.989	<.001
7	1, 2755.999	41.223	<.001	1.111	>	.092	>	17.273	<.001	13.710	<.001	58.372	<.001
8	1, 2755.999	29.986	<.001	4.227	>	.034	>	30.243	<.001	27.014	<.001	65.197	<.001
9	1, 2755.999	19.900	<.001	1.350	>	.012	>	24.572	<.001	26.815	<.001	87.145	<.001
10	1, 2755.999	19.385	<.001	3.969	>	.063	>	23.954	<.001	27.806	<.001	53.095	<.001

Table 3.15b

Results of univariate tests for the effect of rate, across PoA (dental), vowel (/a/) and repetition for intensity ratio

Rate* vowel*PoA *context	INT-R												
	/a/												
	DENTAL												
		VCV		VLCV		VNCV		VRCV		VSCV		VOV	
Repetition	*df*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
1	1, 2756.015	7.395	>	.610	>	1.036	>	4.118	>	16.300	<.001	6.765	>
2	1, 2756.015	6.448	>	.070	>	.506	>	.002	>	.721	>	17.063	<.001
3	1, 2756.015	3.323	>	.972	>	.999	>	2.342	>	.719	>	6.610	>
4	1, 2756.015	1.835	>	.012	>	1.795	>	1.008	>	4.041	>	.671	>
5	1, 2756.015	5.005	>	.057	>	.598	>	5.684	>	7.906	>	1.390	>
6	1, 2756.015	6.094	>	.406	>	.740	>	.704	>	.351	>	6.826	>
7	1, 2756.015	15.342	<.001	.745	>	.269	>	.089	>	.863	>	6.744	>
8	1, 2756.015	6.179	>	.027	>	1.309	>	.252	>	1.127	>	8.259	>
9	1, 2756.015	5.168	>	.010	>	.668	>	.072	>	5.419	>	10.919	.001
10	1, 2756.015	3.945	>	.696	>	.404	>	.771	>	8.931	>	4.202	>

On the basis of the observations reported throughout this section for the effect of the repetition factor in the present study, some conclusions can be drawn with respect to its relevance and the behaviour of the rest of factors under study. Although it could be assumed that results shown for particular comparisons in interaction tests with the repetition factor are probably determined by the number of cases compared, these results advance some of the facts to be observed in further analyses. Most importantly, a clear trend is observed for the non-significant effect of repetitions both as a main effect and across the rest of factors in different interactions. It can be assumed that the effect of repetitions does not intervene in any way in the different realizations. This can be interpreted as evidence of the irrelevant effect of subject and replication in the present study. Thus, replication is not considered to alter dependent variables, which reinforces the random nature of the subject factor (already pondered in the mixed-models analysis) and supports the use of 4 subjects to generalize over potential individual peculiarities. These results provide enough grounds to discard repetition as a factor and focus on the rest of factors and their interactions.

Another important observation in the analysis of the repetition factor is the potential effect of the rest of factors in this study. As reported in the corresponding tables above, rate appears as a very robust effect, since consonant duration and intensity ratio depend quite strongly on rate, even when they are tested across repetition in specific interactions with the rest of factors. This suggests that tests including rate in different interactions can provide relevant evidence to support the hypotheses stated in this study. Accordingly, these tests and the corresponding descriptive data are included in the remaining sections of this chapter. Another strong effect observed in the reported statistical data is that of the context factor, which appears to affect both dependent variables in all interactions. Thus, for the purpose of the present study, it becomes especially relevant to observe its main effect and specific interactions with rate as potential evidence for the stated hypotheses. Finally, the effects of PoA and vowel seem to affect dependent variables to a lesser extent, and appear as less relevant in very specific comparisons. However, their patterns will also be observed as a main effect and especially in interactions with rate as relevant in the remaining sections of this chapter.

The final consideration that arises from this analysis of the repetition factor refers to the behaviour of both dependent variables in lenited realizations. In the results for interactions with repetition, where a smaller number of cases is compared, it has been observed that significant differences in consonant duration may not be paired by significant differences in intensity ratio. Although it is expected that these differences go along in lenited realizations (according to the stated hypotheses), results of the mix-model analysis will shed some light on how dependent variables behave in interactions with the rate factor. They will also allow us to observe how significant differences in both variables under specific conditions may account for consonant lenition degrees. To this aim, it is also important to consider the data provided by spectrographic images in order to analyse and classify the different resulting constriction degrees obtained, and how they are related to the comparison data shown in the statistical analysis.

3.2 Main effects of analysed factors on consonant duration and intensity ratio

Following the inspection of the repetition factor, the first test run in the mixed-models analysis was intended to observe main effects of the factors considered in this study. Main effects include all other conditions for each factor, in which speaking rate is assumed to play a relevant role in lenited realizations of voiced stops. Although main effects offer a very general result, this test gives a clue of the effect power, which also helps to guide further observations in the factor-interaction analysis. Table 3.16 shows the results of fixed effects tests for each factor under analysis for both dependent variables (*F* and *P* values for main effects are included). The data show that rate has a powerful effect on consonant duration, and together with context, it is clearly more robust than the effects of vowel and point of articulation. Similarly, for intensity ratio, both effects (rate and context) are also more prominent than PoA and vowel. In order to illustrate these differences and significance data, graphs are also included in this section.

Table 3.16

Fixed effects test results for main effects of all factors for duration and intensity ratio

MAIN EFFECTS	DEPENDENT VARIABLES	*df*	*F*	*P*
Rate	DURATION	1,2755.991	2492.707	<.001
	INTENSITY RATIO	1,2755.956	602.949	<.001
Vowel	DURATION	1,2755.991	235.944	<.001
	INTENSITY RATIO	1,2755.956	88.837	<.001
PoA	DURATION	2,2756.002	53.112	<.001
	INTENSITY RATIO	2,2756.000	22.629	<.001
Context	DURATION	5,2756.720	825.327	<.001
	INTENSITY RATIO	5,2756.908	933.369	<.001

Besides observing the main effects of factors in the results of fixed effects tests, pairwise comparisons also provide detail of the significance observed, especially in the cases where more than two levels are included for a given factor. For the effect of rate on consonant duration and intensity ratio, where the comparison target includes only two levels, pairwise comparison tables and graphs show detail of means and also represent significance graphically. Table 3.17 shows mean data for slow and fast rates and the corresponding comparison significance for both duration and intensity ratio. Figure 3.1, in turn, plots these comparisons.

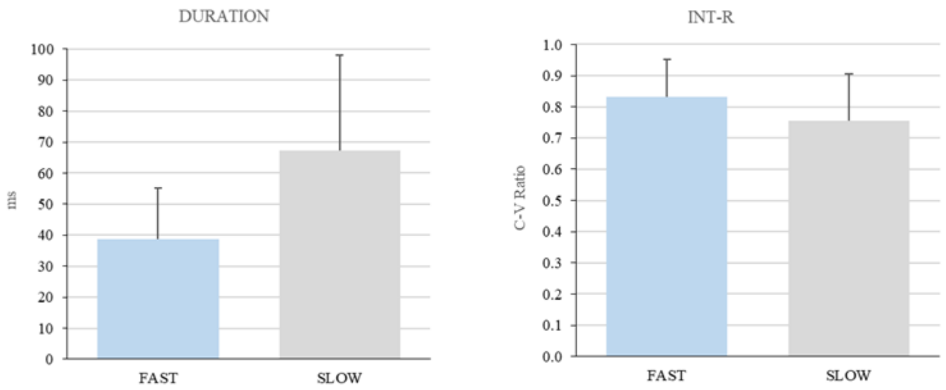
Table 3.17

Results of pairwise comparison tests for main effects of rate for duration and intensity ratio

DURATION				INT-R			
Rate			FAST vs SLOW	Rate			FAST vs SLOW
	M	*SD*	*mean comparisons (p)*		*M*	*SD*	*mean comparisons (p)*
FAST	38.812	16.490	<.001	FAST	.832	.119	<.001
SLOW	67.256	30.675		SLOW	.756	.151	

Figure 3.1

Mean values for duration and intensity ratio across rate as a main effect



The same type of result can be observed for the vowel factor, for which differences in mean values for both duration and intensity ratio appear as significant. Table 3.18 and Figure 3.2 show and represent the detail of mean data and comparisons. These results suggest that consonant constriction degree is affected significantly by the tested factors.

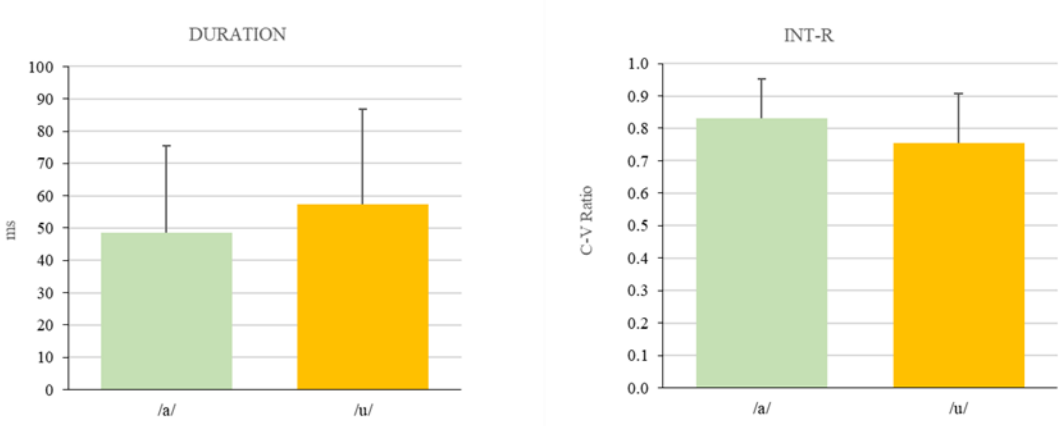
Table 3.18

Pairwise comparison results for main effect of vowel for duration and intensity ratio

DURATION				INT-R			
Vowel			/a/ vs /u/	Vowel			/a/ vs /u/
	M	*SD*	*mean comparisons (p)*		*M*	*SD*	*mean comparisons (p)*
/a/	48.658	26.813	<.001	/a/	.809	.138	<.001
/u/	57.410	29.333		/u/	.779	.143	

Figure 3.2

Mean values for duration and intensity ratio across vowel as a main effect



In order to explore main effects of context and point of articulation, pairwise comparison tests are especially useful to observe how the relevance shown in the results for fixed effects is specified in individual comparisons. In the case of point of articulation, pairwise comparison results show that /b/ is significantly longer than /d/ and /g/ when all other conditions are included. Differences in consonant duration between /d/ and /g/ appear as non-significant. By contrast, results also show that intensity ratio behaves differently across point of articulation. Comparisons suggest that constriction degrees are significantly different when /d/ is involved, whereas /b/ and /g/ do not appear as significantly different with respect to intensity ratio. Table 3.19 shows mean values and significance data for these pairwise comparisons. They are also illustrated in Figure 3.3.

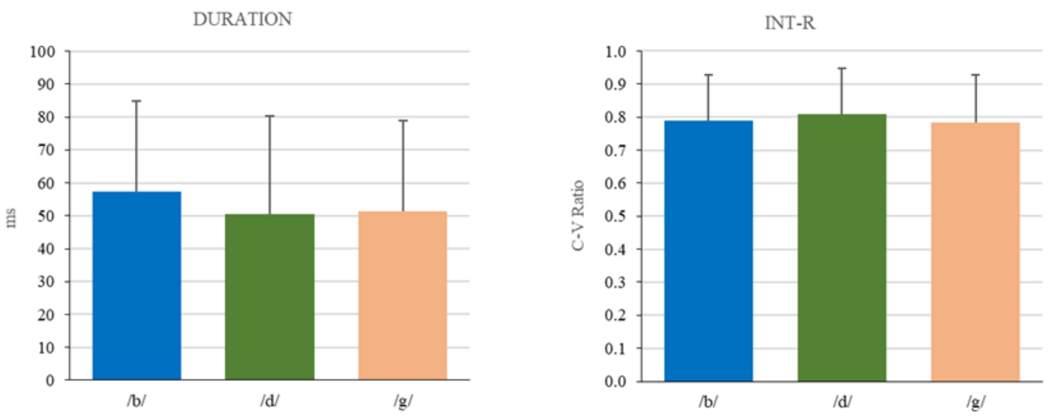
Table 3.19

Pairwise comparison results for main effect of point of articulation for duration and intensity ratio

DURATION						INT-R					
PoA			/b/	/d/	/g/	PoA			/b/	/d/	/g/
	M	*SD*	*mean comparisons (p)*				*M*	*SD*	*mean comparisons (p)*		
/b/	57.167	27.800		<.001	<.001	/b/	.789	.139		<.001	0.466
/d/	50.624	29.585			0.974	/d/	.808	.140			<.001
/g/	51.311	27.448				/g/	.784	.144			

Figure 3.3

Mean values for duration and intensity ratio across point of articulation as a main effect



The analysis of the context factor also yielded some significance results for consonant duration as a main effect (as shown in Table 3.16). More specifically, pairwise comparisons show the cases that determine this significance. The main effect of context for duration is significant in some pairwise comparisons, that is, VNCV, VOV, and VLCV (see Table 3.20). This suggests that differences in consonant durations are only relevant in those contexts that are not expected to undergo lenition processes. These include homorganic /d/ in the case of VLCV, voiceless stops (VOV) and nasal contexts (VNCV). These significant differences suggest some regular realization patterns for these contexts even with the potential effect of other factors. On the contrary, the differences in consonant duration are not significant in pairwise comparisons involving VCV, VRCV and VSCV. This may be due to the variability exhibited in the realization of target consonants when they are flanked by /r/ (VRCV) and /s/ (VSCV), especially in VRCV, which becomes similar to intervocalic realizations regardless of the effect of other factors (see Figure 3.4).

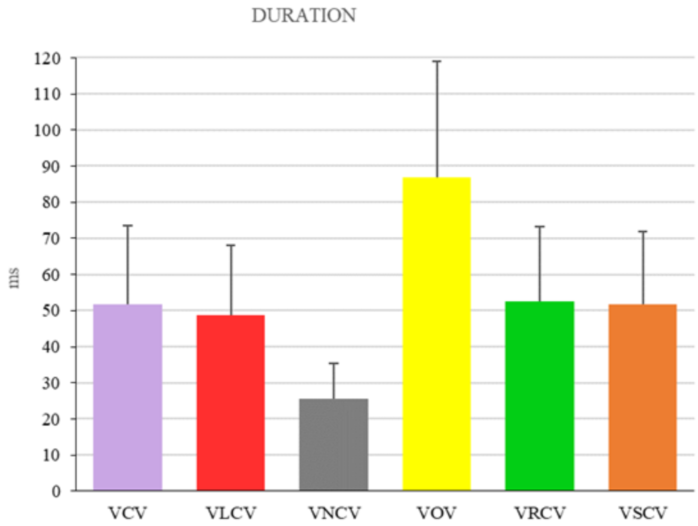
Table 3.20

Pairwise comparison results for main effect of context for duration

DURATION								
Context			VCV	VLCV	VNCV	VOV	VRCV	VSCV
	M	*SD*	*mean comparisons (p)*					
VCV	51.713	21.936		.003	<.001	<.001	1	1
VLCV	48.824	19.153			<.001	<.001	<.001	.004
VNCV	25.563	9.908				<.001	<.001	<.001
VOV	86.899	32.157					<.001	<.001
VRCV	52.521	20.835						1
VSCV	51.632	20.299						

Figure 3.4

Mean values for duration across context as a main effect



In the case of intensity ratio, pairwise comparisons also show the results for individual comparisons between the different levels. The context factor affects intensity ratio when the rest of conditions are included (see Table 3.21). Pairwise comparisons reveal that differences in intensity ratio are all significant, except for the VCV vs VLCV comparison. These results show that the effect of context is more robust for intensity ratio than for duration, with more significant differences in pairwise comparisons (also see Figure 3.5).

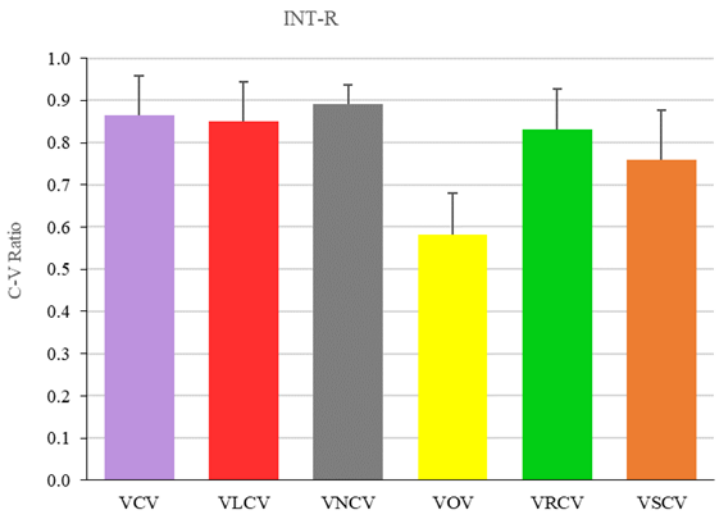
Table 3.21

Pairwise comparison results for main effect of context on intensity ratio

			INT-R					
Context			VCV	VLCV	VNCV	VOV	VRCV	VSCV
	M	*SD*	*mean comparisons (p)*					
VCV	.865	.094		1	<.001	<.001	<.001	<.001
VLCV	.850	.092			<.001	<.001	<.001	<.001
VNCV	.890	.047				<.001	<.001	<.001
VOV	.582	.099					<.001	<.001
VRCV	.831	.097						<.001
VSCV	.759	.118						

Figure 3.5

Mean values for intensity ratio across context as a main effect



In the light of the results obtained for main effects, it can be concluded that it is necessary to observe the results of factor-interaction tests for different purposes. As suggested previously, interaction tests will provide evidence to discern between the potential effects of each factor relevant to this study. Interactions with the rate factor will be the focus of these analyses in order to test the hypothesis presented in this study. Another aspect that deserves attention in further statistical analyses refers to the behaviour of both dependent variables (duration and intensity ratio) in lenited realizations. It has been observed that for main effects these variables may not go along in terms of the significance obtained. Therefore, interaction tests will allow to observe the effect of combined factors on both variables and how they behave in different consonant constriction degrees identified among lenited realizations in the present study.

3.3 Effects of speaking rate on consonant duration

The effect of speaking rate on both dependent variables embodies a very important condition in this study to provide evidence that supports the stated hypotheses. Thus, in the mixed-model analysis run in this study, different tests involving rate are relevant to prove its prominent role in the production of lenited voiced stops in Castilian Spanish. In order to provide this evidence, speaking rate has been tested in interaction with the rest of variables under study, in two-way, three-way and multiple-mode interactions. These interactions appear as significant in all cases for consonant duration, as shown in Table 3.22. In this section the results of univariate tests will shade light on the effect of individual factors in the interactions analysed. In the same line, pairwise comparisons will provide detail of differences across the specific levels for each factor with the specific significance data. Although pairwise comparisons may become redundant for two-level factors, they are also provided to show the detail of specific mean values. They will also be supported by graphs to illustrate the observed mean differences (including mean values and standard deviation bars) for dependent variables as a function of factor interaction.

Table 3.22

Fixed effects test results for two-way, three-way and multiple interaction for duration[5]

INTERACTION	DEPENDENT VARIABLE	*df*	*F*	*P*
rate * context	DURATION	10,2756.269	612.260	<.001
rate * PoA	DURATION	4,2756.001	39.448	<.001
rate * vowel	DURATION	2,2756.001	157.286	<.001
rate * context * PoA	DURATION	20,2755.999	11.259	<.001
rate * context * vowel	DURATION	10,2756.023	9.641	<.001
rate * PoA * vowel	DURATION	4,2756.001	25.491	<.001
rate * context * PoA * vowel	DURATION	71,2756.033	172.988	<.001

It is important to clarify at this point that, although the focus of the results reported lies on the effect of the rate factor, attention is also drawn to the rest of factors in their interactions with rate. In the case of two-way interactions, it will help to highlight the robustness of the effect of rate by comparison. In addition, it can shed some light on how rate alters the effect of other factors as factor levels are compared across rates. In the case of three-way and multiple interaction, specific detail is only provided for the effect of rate, as it is considered that two-way interaction results provide enough detail for other factors. However, univariate tests are included to observe other general, relevant effects of factors across rates.

3.3.1 Two-way interactions

The results obtained for the effects of rate in interaction with another factor are considered relevant to provide evidence of the power and role of the rate condition. As mentioned in Chapter 1, previous studies (Carrasco et al, 2012; Kingston, 2008; Recasens, 2015; Romero, 1994; Soler & Romero, 1999, 2013) have shown that context, vowel and point of articulation play a role both in the occurrence of lenited realizations and in different resulting constriction degrees. Thus, two-way interactions can show whether the effect of a given factor is affected by speaking rate, and how the strength of factor effects may compare. These data can contribute to supporting the hypotheses in the present study.

[5] Specific detail of significance for multiple-interaction results is not provided as it is not considered relevant for further evidence of the effect of time

3.3.1.1 Rate*context interaction

In the rate*context interaction the results of the mixed-models analysis show that both effects are significant when analysed across each other for consonant duration. Table 3.23 shows how the effect of rate appears as a very robust condition in interaction with contexts, and differences are all significant involving speaking rate as a function of context.

Table 3.23

Results of univariate tests for the effect of rate across context for duration

DURATION			
Rate*context	*df*	*F*	*P*
VCV	1,2756.001	738.49	<.001
VLCV	1,2756.001	234.5	<.001
VNCV	1,2756.001	27.655	<.001
VOV	1,2756.001	1918.5	<.001
VRCV	1,2756.001	587.6	<.001
VSCV	1,2756.001	502.54	<.001

Likewise, as shown in Table 3.24, pairwise comparisons also reveal how consonant durations are all significantly shorter at the fast rate, which is generally associated with more lenited realizations. However, this is not necessarily true for all contexts, and these significant differences in duration have to be interpreted in the light of intensity ratio results for the different realizations obtained (described in section 3.4). These results will help to determine how differences in consonant duration between fast and slow rates are related to lenition or voicing phenomena. Further discussion in Chapter 4 will focus on the details of the processes involved in the production of voiced plosives at different speaking rates. Figure 3.6 shows the mean values for consonant durations for the two rates and the six contexts, and illustrates the significant differences observed.[6]

[6] df values and F values are not shown in pairwise comparison tables to avoid excessive table load.

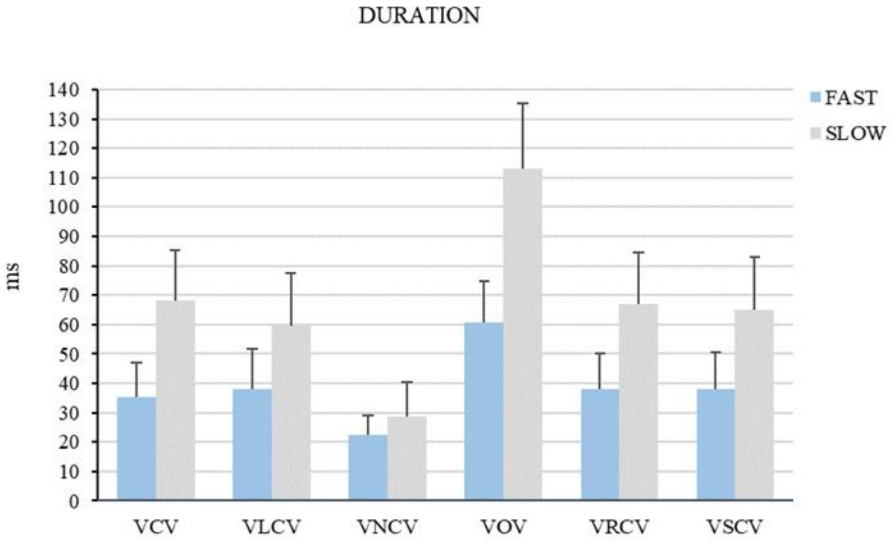
Table 3.24

Pairwise comparison results for the effect of rate across context for duration

DURATION										
Context					VCV	VLCV	VNCV	VOV	VRCV	VSCV
Rate	FAST		SLOW		FAST vs SLOW					
	M	*SD*	*M*	*SD*	*mean comparisons (p)*					
VCV	35.391	11.446	68.035	17.271	<.001					
VLCV	38.203	13.456	59.444	18.105		<.001				
VNCV	22.404	6.717	28.721	11.471			<.001			
VOV	60.590	14.220	113.207	21.913				<.001		
VRCV	37.962	12.070	67.081	17.280					<.001	
VSCV	38.168	12.224	65.097	17.673						<.001

Figure 3.6

Mean values for consonant duration for the effect of rate across context



In the rate*context interaction, the context factor also has some significant effect on consonant duration as a function of rate, as shown in Table 3.25 for univariate tests. In this case, however, it is necessary to obtain the results of pairwise comparisons to observe significant differences in consonant durations for specific levels (the different contexts in these comparisons). Table 3.26 shows that, in general, these results are not so different from the results obtained for context as a main effect. In the case of the fast rate, pairwise comparisons display significant differences for comparisons with VOV and VNCV. In fact, a longer duration can be expected for the VOV context, since it includes the voiceless plosives (/p, t, k/) in intervocalic position. These have been described as having longer durations than voiced plosive consonants (Hualde, 2005; Martínez Celdrán, 1984, 1991b), and they appear as such in these pairwise comparisons.

Table 3.25

Results of univariate tests for the effect of context across rate for duration

DURATION			
Context*rate	*df*	*F*	*P*
FAST	5,2756.304	210.216	<.001
SLOW	5,2756.304	1014.430	<.001

Table 3.26

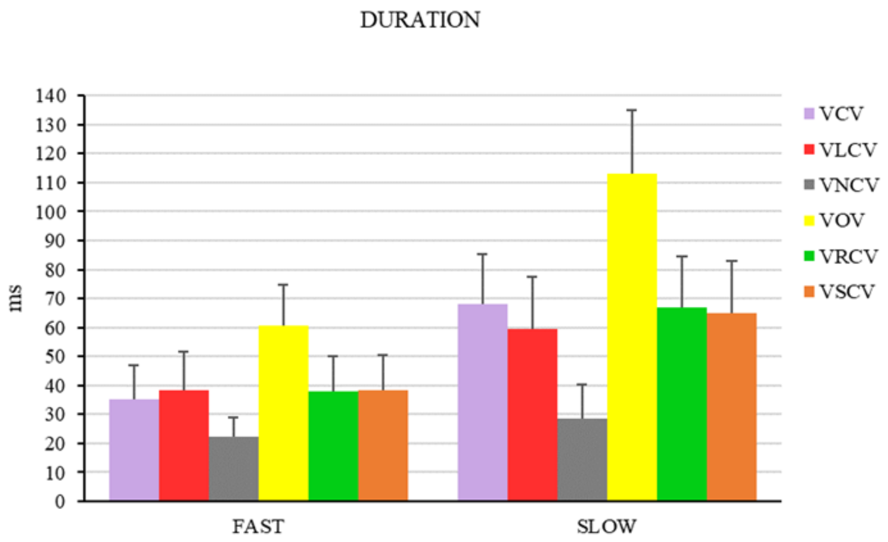
Pairwise comparison results for the effect of context across rate for duration

DURATION																
Rate	FAST								SLOW							
Context			VCV	VLCV	VNCV	VOV	VRCV	VSCV			VCV	VLCV	VNCV	VOV	VRCV	VSCV
	M	*SD*	*mean comparisons (p)*						*M*	*SD*	*mean comparisons (p)*					
VCV	35.391	11.446		1	<.001	<.001	.486	.313	68.035	17.271		<.001	<.001	<.001	1	.218
VLCV	38.203	13.456			<.001	<.001	1	1	59.444	18.105			<.001	<.001	<.001	<.001
VNCV	22.404	6.717				<.001	<.001	<.001	28.721	11.471				<.001	<.001	<.001
VOV	60.590	14.220					<.001	<.001	113.207	21.913					<.001	<.001
VRCV	37.962	12.070						1	67.081	17.280						1
VSCV	38.168	12.224							65.097	17.673						

In the case of the slow rate, pairwise comparisons display slightly different results, and more significant differences between specific contexts can be observed. All comparisons appear as significant except for VRCV vs VCV and VSCV vs VCV. These results for the context*rate interaction show how the rate factor alters the effect of context and how this effect acts differently across the two rates with respect to consonant durations. These results can also be regarded as evidence of the strength of the rate factor and how different durations are associated with different constriction degrees in the light of intensity ratio results. Figure 3.7 displays these comparisons graphically.

Figure 3.7

Mean values for consonant duration for the effect of context across rate



3.3.1.2 Rate*PoA interaction

In order to provide more evidence of the powerful effect of rate, rate*PoA interaction results also become relevant in this study. The results obtained in the mixed-models analysis show that both effects are significant again when analysed across each other for consonant duration. As shown in Table 3.27 the effect of rate yields significant differences across points of articulation in all cases, which makes it a very robust condition in this interaction too. Thus, consonant durations are all significantly different in the fast-vs-slow comparison across the three consonants under study (/b, d, g/). These results are supported by pairwise comparison tests as shown in Table 3.28. Figure 3.8 also represents the comparisons of mean values and their significance.

Table 3.27

Results of univariate tests for the effect of rate across PoA for consonant duration

DURATION			
Rate*PoA	*df*	*F*	*P*
/b/	1,2756.001	863.043	<.001
/d/	1,2756.001	1276.218	<.001
/g/	1,2756.001	1025.266	<.001

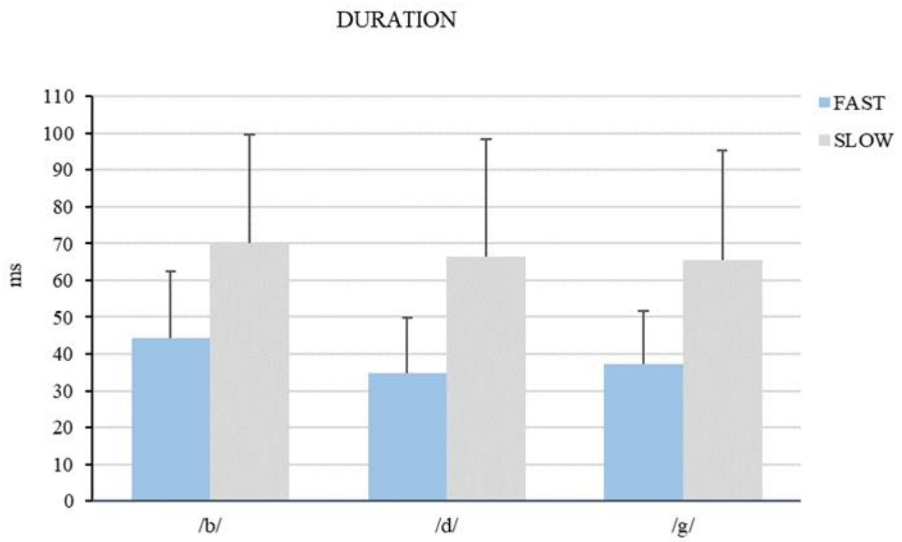
Table 3.28

Pairwise comparison results for the effect of rate across PoA for duration

DURATION							
PoA					/b/	/d/	/g/
Rate	FAST		SLOW		FAST vs SLOW		
	M	*SD*	*M*	*SD*	*mean comparisons (p)*		
/b/	44.247	18.302	70.087	29.629	<.001		
/d/	34.945	15.044	66.303	32.147		<.001	
/g/	37.243	14.442	65.380	30.053			<.001

Figure 3.8

Mean values for consonant duration for the effect of rate across PoA



In the same line as the previous two-way interactions, the results of univariate tests for the effect of PoA across rate also indicate that differences in consonant duration are significant, as displayed in Table 3.29. Like the effect of context, the effect of PoA also requires further observation for individual comparisons between the levels and their significance.

Table 3.29

Results of univariate tests for the effect of PoA across rate for consonant duration

DURATION			
PoA*rate	*df*	*F*	*P*
FAST	2,2756.001	62.367	<.001
SLOW	2,2756.001	16.529	<.001

Table 3.30, in turn, shows the results of pairwise comparisons, which appear to match the results for PoA as a main effect. Consonants are not significantly different in the dental-vs-velar comparison for either the fast rate or the slow rate. For the rest of comparisons (labial vs dental and labial vs velar), consonant durations are significantly different as a function of rate. Figure 3.9 shows these differences graphically.

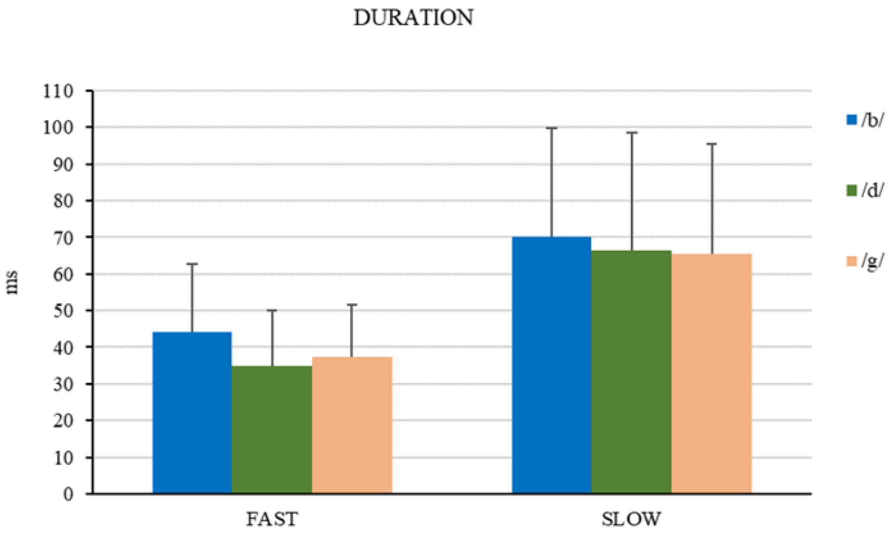
Table 3.30

Pairwise comparison results for the effect of PoA across rate for duration

DURATION										
Rate	FAST					SLOW				
PoA			/b/	/d/	/g/			/b/	/d/	/g/
	M	*SD*	*mean comparisons (p)*			*M*	*SD*	*mean comparisons (p)*		
/b/	44.247	18.302		<.001	<.001	70.087	29.629		<.001	<.001
/d/	34.945	15.044			.024	66.303	32.147			.863
/g/	37.243	14.442				65.380	30.053			

Figure 3.9

Mean values for consonant duration for the effect of PoA across rate



3.3.1.3 Rate*vowel interaction

The final two-way interaction reported on involves the effect of rate and vowel on consonant duration, with test results yielding significant differences in consonant duration. Table 3.31 shows that consonants are significantly shorter for the fast rate both for /a/ and /u/. In this case, pairwise comparisons in Table 3.32 help to observe the specific mean values that yielded this significance, while Figure 3.10 illustrates the results.

Table 3.31

Results of univariate tests for the effect of rate across vowel for consonant duration

DURATION			
Rate*vowel	*df*	*F*	*P*
/a/	1,2756.001	1402.427	<.001
/u/	1,2756.001	1745.097	<.001

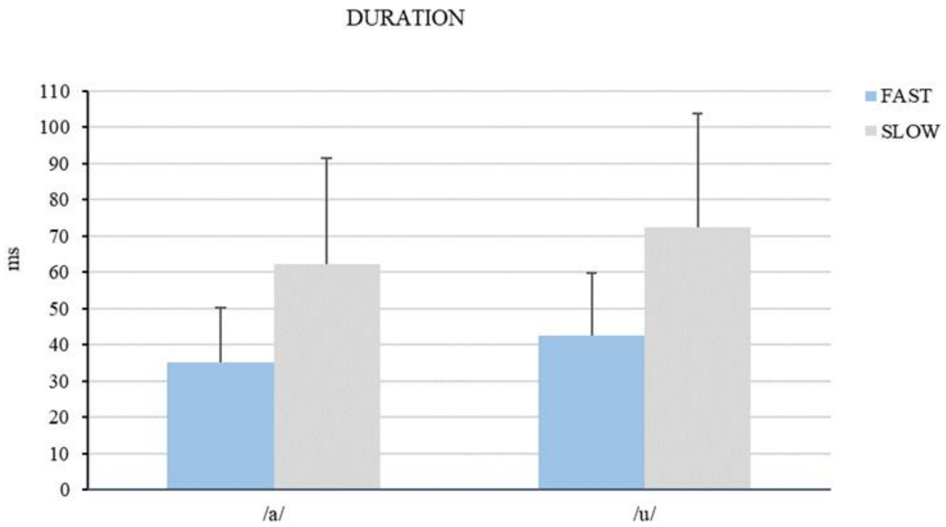
Table 3.32

Pairwise comparison results for the effect of rate across vowel for duration

DURATION						
Vowel					/a/	/u/
Rate	FAST		SLOW		FAST vs SLOW	
	M	*SD*	*M*	*SD*	*mean comparisons (p)*	
/a/	35.204	14.906	62.112	29.227	<.001	
/u/	42.419	17.204	72.400	31.242		<.001

Figure 3.10

Mean values for consonant duration for the effect of rate across vowel



Finally, as shown in Table 3.33, the vowel factor also conditions consonant duration for both the fast and the slow rates. The target consonants (/b/, /d/, /g/) are significantly shorter for /a/ than for /u/ in both rates separately. Although this factor only specifies two levels, pairwise comparisons also help to support the significance observed in univariate tests. Thus, Table 3.34 and Figure 3.11 illustrate mean values and comparison significance for the effect of vowel.

Table 3.33

Results of univariate tests for the effect of vowel across rate for consonant duration

DURATION			
Vowel*rate	*df*	*F*	*P*
FAST	1,2756.001	103.703	<.001
SLOW	1,2756.001	210.870	<.001

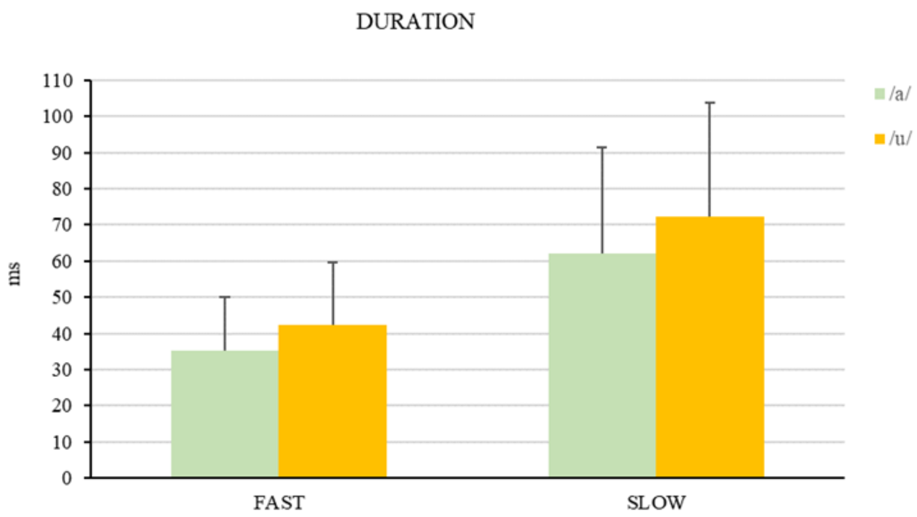
Table 3.34

Pairwise comparison results for the effect of vowel across rate for duration

	DURATION					
Rate	FAST			SLOW		
Vowel			/a/ vs /u/			/a/ vs /u/
	M	*SD*	*mean comparisons (p)*	*M*	*SD*	*mean comparisons (p)*
/a/	35.204	14.906	<.001	62.112	29.227	<.001
/u/	42.419	17.204		72.400	31.242	

Figure 3.11

Mean values for consonant duration for the effect of vowel across rate



In the light of these results and for further discussion, it remains to be confirmed whether shorter consonant durations go along with intensity-ratio values corresponding to more lenited consonants in the case of flanking /a/. These data are shown in section 3.4. More detail of consonant duration is provided below in three-way interactions, where the focus is placed on the effect of rate and its strength. For this purpose, only univariate tests are included to observe the effect of other factors in these interactions.

3.3.2 Three-way interactions

In order to obtain a more accurate picture of the effect of rate on consonant duration, three-way interaction tests involving the effect of rate have also been conducted. These tests can help to observe the robustness of the effect of factors by focusing the analysis on each of them in more specific comparisons (across the other two factors involved). This allows us to discern how each effect is responsible for the resulting significance shown in the outcome for these interactions. These results are displayed in the corresponding tables for each factor in each of the analysed interactions. However, in order to avoid an overloaded section, pairwise comparison tables are only included for the effect of rate, while tables for the effect of context, PoA and vowel are shown in Appendix D. Regarding graphs, only those for the effect of rate are shown in three-way interactions.

3.3.2.1 Rate*context*PoA interaction

The results of univariate tests for the rate*context*PoA interaction show that the three factors have a major effect on consonant durations. Firstly, as Table 3.35 reveals, rate has a significant effect on duration when analysed by PoA and context. The detail also shows that consonant duration is not affected significantly by rate in the case of /d/ and /g/ when flanked by nasals (VNCV). For the rest of contexts, though, rate shows the same powerful effect on consonant duration as for the broader two-way comparisons.

Table 3.35

Results of univariate tests for the effect of rate across context and PoA for consonant duration

	DURATION								
Rate*PoA	/b/			/d/			/g/		
Context	*df*	*F*	*P*	*df*	*F*	*P*	*df*	*F*	*P*
VCV	1,2756.076	247.723	<001	1,2756.076	297.375	<001	1,2756.064	308.805	<001
VLCV	1,2756.015	112.549	<001	1,2756.015	38.731	<001	1,2756.009	135.871	<001
VNCV	1,2756.025	30.665	<001	1,2756.025	4.246	.039	1,2756.014	4.775	.029
VOV	1,2756.053	597.669	<001	1,2756.053	946.904	<001	1,2756.042	690.024	<001
VRCV	1,2756.104	125.673	<001	1,2756.104	370.393	<001	1,2756.081	214.365	<001
VSCV	1,2756.042	111.934	<001	1,2756.042	337.367	<001	1,2756.008	162.763	<001

In similar fashion, univariate tests show that the effect of context across PoA and rate are also significant. Table 3.36 displays how differences between context levels are significant across /b/, /d/, and /g/ and the two speaking rates. In the case of point of articulation (Table 3.37), its effect seems to be different for the two speaking rates (fast and slow). Consonant duration is not significantly different across point of articulation in the case of consonants flanked by nasals (VNCV) and vowels (VCV) for the fast rate, and for VCV and VSCV for the slow rate. Again, this suggests that rate alters the effect of factors, since duration differences between b/, /d/ and /g/ appear as non-significant for VNCV in the fast rate, while they are significant for the slow rate.

Table 3.36

Results of univariate tests for the effect of context across rate and PoA for consonant duration

DURATION									
Context*PoA	/b/			/d/			/g/		
Rate	*df*	*F*	*P*	*df*	*F*	*P*	*df*	*F*	*P*
FAST	5, 2756.136	110.840	<001	5, 2756.136	75.384	<001	5, 2756.136	67.020	<001
SLOW	5, 2756.163	359.209	<001	5, 2756.159	483.224	<001	5, 2756.129	362.405	<001

Table 3.37

Results of univariate tests for the effect of PoA across context and rate for consonant duration

DURATION						
PoA*Rate	FAST			SLOW		
Context	*df*	*F*	*P*	*df*	*F*	*P*
VCV	2, 2756.001	4.567	.010	2, 2755.999	4.531	.011
VLCV	2, 2756.001	13.848	<001	2, 2755.988	51.432	<001
VNCV	2, 2756.001	3.146	.043	2, 2755.999	19.519	<001
VOV	2, 2756.001	28.690	<001	2, 2755.999	20.106	<001
VRCV	2, 2756.001	21.424	<001	2, 2755.999	8.081	<001
VSCV	2, 2756.001	27.055	<001	2, 2756.014	1.213	.297

Although univariate tests for the effect of rate show how this factor affects consonant durations across PoA and context (see Table 3.35), pairwise comparisons also help to illustrate this effect together with the corresponding mean data. Table 3.38 shows how consonant durations are not significantly different in the fast-vs-slow comparison for /d/ and /g/ in the case of the VNCV context only. However, the effect of rate appears as a determining factor in the rest of comparisons by context and PoA. Figure 3.12 below also illustrates this effect by representing consonant duration mean values.

Table 3.38

Pairwise comparison results for the effect of rate across context and PoA for duration

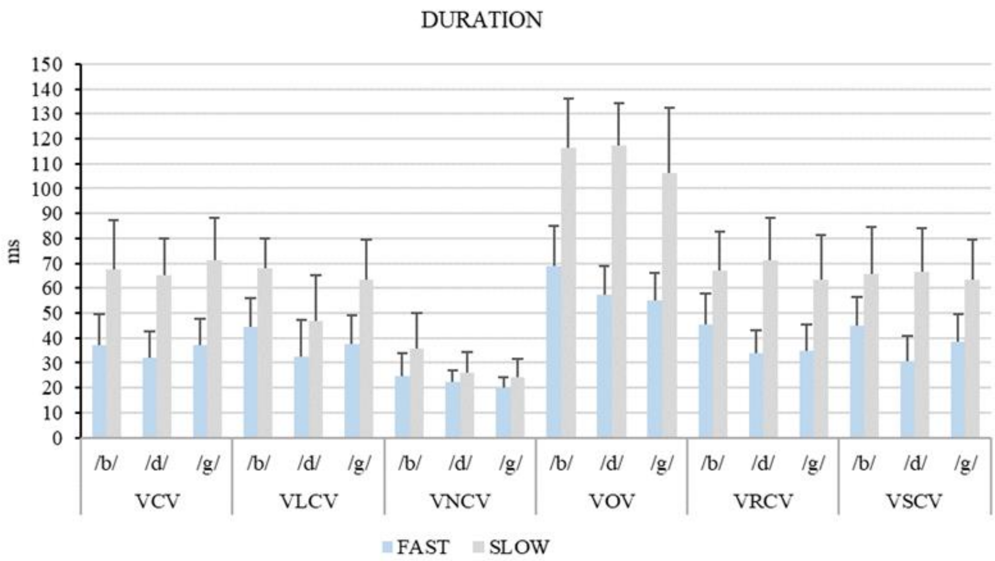
DURATION											
		VCV					VLCV				
Context*PoA				/b/	/d/	/g/			/b/	/d/	/g/
Rate				F. vs S.	F. vs S.	F. vs S.			F. vs S.	F. vs S.	F. vs S.
		M	*SD*	*mean comparisons (p)*			*M*	*SD*	*mean comparisons (p)*		
/b/	FAST	37.024	12.698	<.001			44.403	11.813	<.001		
	SLOW	67.513	19.702				68.133	11.625			
/d/	FAST	32.011	10.485		<.001		32.692	14.329		<.001	
	SLOW	65.416	14.465				46.612	18.455			
/g/	FAST	37.136	10.385			<.001	37.516	11.575			<.001
	SLOW	71.177	16.964				63.588	16.031			

DURATION											
		VNCV					VOV				
Context*PoA				/b/	/d/	/g/			/b/	/d/	/g/
Rate				F. vs S.	F. vs S.	F. vs S.			F. vs S.	F. vs S.	F. vs S.
		M	*SD*	*mean comparisons (p)*			*M*	*SD*	*mean comparisons (p)*		
/b/	FAST	24.883	9.179	<.001			68.956	16.038	<.001		
	SLOW	35.610	14.373				116.312	19.670			
/d/	FAST	22.303	4.870		.039		57.568	11.128		<.001	
	SLOW	26.295	7.866				117.176	17.276			
/g/	FAST	20.027	4.072			.029	55.248	11.030			<.001
	SLOW	24.260	7.446				106.132	26.286			

DURATION											
		VRCV					VSCV				
Context*PoA				/b/	/d/	/g/			/b/	/d/	/g/
Rate				F. vs S.	F. vs S.	F. vs S.			F. vs S.	F. vs S.	F. vs S.
		M	*SD*	*mean comparisons (p)*			*M*	*SD*	*mean comparisons (p)*		
/b/	FAST	45.253	12.636	<.001			45.003	11.280	<.001		
	SLOW	66.969	15.578				65.497	19.154			
/d/	FAST	33.749	9.350		<.001		30.785	10.247		<.001	
	SLOW	71.029	17.308				66.365	17.922			
/g/	FAST	34.883	10.594			<.001	38.715	10.818			<.001
	SLOW	66.969	15.578				63.428	15.880			

Figure 3.12

Mean values for consonant duration for the effect of rate across context and PoA



3.3.2.2 Rate*context*vowel interaction

The second three-way interaction analysed in this study can also provide evidence of the effect of speaking rate on consonant duration in the different realizations of voiced plosives. The results of univariate tests for the rate*context*vowel interaction show that the three factors have a major effect on consonant durations, although significance must be further observed in pairwise comparisons between factor levels for the necessary detail. The effect of rate seems to be powerful for the interaction with vowel and context, as it is shown in Table 3.39. It can be observed that differences in consonant duration only lose some significance when the VNCV context is involved, as it occurred for the rate*context*PoA interaction, and differences between fast and slow are not significant for this context in the case of /a/.

Table 3.39

Results of univariate tests for the effect of rate across context and vowel for consonant duration

DURATION						
Rate*Vowel	/a/			/u/		
Context	*df*	*F*	*P*	*df*	*F*	*P*
VCV	1, 2756.143	431.818	<001	1, 2756.096	420.219	<001
VLCV	1, 2756.032	109.650	<001	1, 2755.980	163.572	<001
VNCV	1, 2756.076	8.463	.004	1, 2756.062	25.797	<001
VOV	1, 2756.109	1046.002	<001	1, 2756.062	1169.122	<001
VRCV	1, 2756.109	294.697	<001	1, 2756.140	386.323	<001
VSCV	1, 2756.102	242.043	<001	1, 2756.076	342.054	<001

Univariate tests also show significance for the effect of context and vowel in this three-way interaction. For the effect of context, differences in consonant duration are significant by rate and vowel, as shown in Table 3.40. Therefore, it would become necessary to look into pairwise comparisons to determine which contexts really play a role in these differences and whether differences have some similarities with other three-way comparisons involving context. This detail is not reported here, as for the effect of context, two-way interaction has shown relevant differences, and further data is considered beyond the scope of this section. In addition, univariate tests reveal how the effect of vowel is significant in all cases, except for the VNCV context, in which differences in consonant duration for /a/ and /u/ are not significant in any of the two rates. Table 3.41 shows how durations appear to be determined by the vowel factor for the rest of contexts across rates.

Table 3.40

Results of univariate tests for the effect of context across rate and vowel for consonant duration

DURATION						
Context*Vowel	/a/			/u/		
Rate	*df*	*F*	*P*	*df*	*F*	*P*
FAST	5, 2756.213	109.920	<001	5, 2756.213	143.370	<001
SLOW	5, 2756.251	547.950	<001	5, 2756.218	631.141	<001

Table 3.41

Results of univariate tests for the effect of vowel across context and rate for consonant duration

DURATION						
Vowel*Rate	FAST			SLOW		
Context	*df*	*F*	*P*	*df*	*F*	*P*
VCV	1, 2756.040	74.059	<001	1, 2756.006	69.302	<001
VLCV	1, 2755.974	36.169	<001	1, 2755.949	69.427	<001
VNCV	1, 2756.073	1.247	.264	1, 2756.073	1.109	.292
VOV	1, 2756.040	16.886	<001	1, 2756.006	35.520	<001
VRCV	1, 2755.939	28.195	<001	1, 2756.006	60.812	<001
VSCV	1, 2756.107	16.909	<001	1, 2756.006	49.688	<001

Besides the outcome shown in univariate tests, pairwise comparisons illustrate how speaking rate is relevant when fast and slow realizations are compared, except for the VNCV context for /a/. As shown in Table 3.42, the difference shown by mean data in the table is not significant in this case, while it is significant for the rest of comparisons across the different contexts and the two vowels. Again, the effect of speaking rate seems to play a determining role in consonant duration even when data are analysed across the specific levels. Figure 3.13 below also illustrates the differences in consonant duration for fast and slow rates across vowel and context.

Table 3.42

Pairwise comparison results for the effect of rate across context and vowel for duration

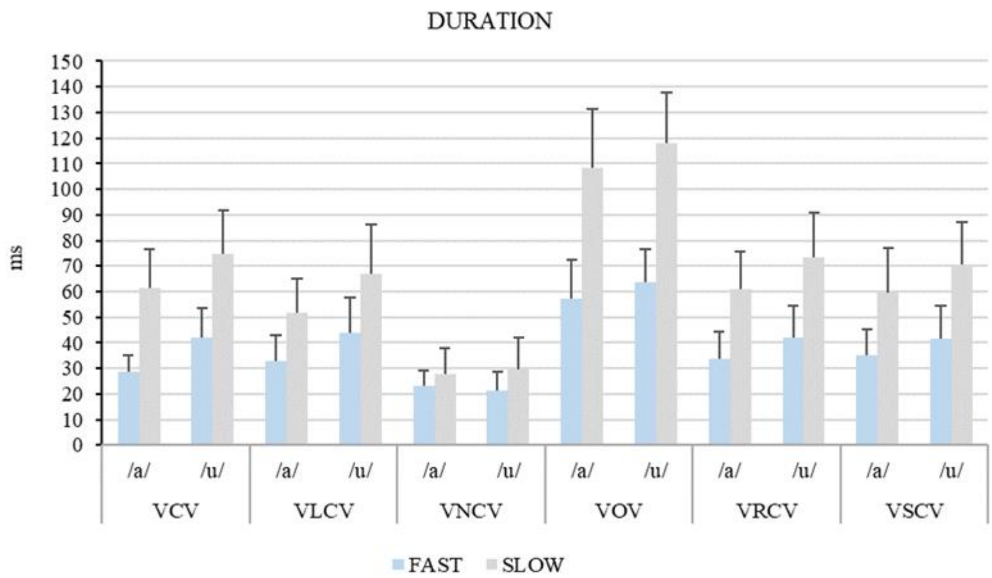
DURATION									
		VCV				VLCV			
Context*Vowel				/a/	/u/			/a/	/u/
Rate				FAST vs SLOW				FAST vs SLOW	
		M	*SD*	*mean comparisons (p)*		*M*	*SD*	*mean comparisons (p)*	
/a/	FAST	28.585	6.657	<.001		32.712	10.121	<.001	
	SLOW	61.452	14.954			51.836	13.116		
/u/	FAST	42.196	11.199		<.001	43.695	14.167		<.001
	SLOW	74.618	16.971			67.053	19.239		

				VNCV				VOV	
Context*Vowel				/a/	/u/			/a/	/u/
Rate				FAST vs SLOW				FAST vs SLOW	
		M	*SD*	*mean comparisons (p)*		*M*	*SD*	*mean comparisons (p)*	
/a/	FAST	23.287	5.946	.004		57.341	15.033	<.001	
	SLOW	27.888	10.223			108.494	23.004		
/u/	FAST	21.521	7.328		<.001	63.840	12.603		<.001
	SLOW	29.554	12.584			117.920	19.759		

DURATION									
				VRCV				VSCV	
Context*Vowel				/a/	/u/			/a/	/u/
Rate				FAST vs SLOW				FAST vs SLOW	
		M	*SD*	*mean comparisons (p)*		*M*	*SD*	*mean comparisons (p)*	
/a/	FAST	33.763	10.431	<.001		34.916	10.341	<.001	
	SLOW	60.914	14.854			59.522	17.324		
/u/	FAST	42.161	12.174		<.001	41.420	13.109		<.001
	SLOW	73.248	17.388			70.671	16.262		

Figure 3.13

Mean values for consonant duration for the effect of rate across context and vowel



3.3.2.3 Rate*PoA*vowel interaction

The last three-way interaction analysed in this study involves the effect of rate*context*PoA on the dependent variables. The results of univariate tests reveal that the three factors have an effect on consonant durations, although the effect of vowel seems to be less robust. As Table 3.43 shows, rate has a significant effect on duration when analysed by PoA and vowel. Consonant durations are significantly different for /b/, /d/ and /g/ as a function of rate, for both vowels (/a/ and /u/).

Table 3.43

Results of univariate tests for the effect of rate across PoA and vowel for consonant duration

DURATION						
Rate*Vowel	/a/			/u/		
PoA	*df*	*F*	*P*	*df*	*F*	*P*
/b/	1, 2756.056	355.846	<001	1, 2756.994	678.365	<001
/d/	1, 2756.051	752.392	<001	1, 2756.010	675.374	<001
/g/	1, 2756.040	540.396	<001	1, 2756.991	659.052	<001

As univariate tests also show in Table 3.44 and Table 3.45, both the PoA factor and the vowel factor play a role in this three-way interaction for consonant duration. The effect of point of articulation, whether the consonant is /b/, /d/ or /g/ seems to affect consonant duration significantly (Table 3.44). Likewise, univariate tests reveal that consonant durations are also significantly different as a function of vowel across the two rates and the three consonants under study (/b/, /d/, and /g/), except for the case of /d/ (Table 3.45).

Table 3.44

Results of univariate tests for the effect of PoA across rate and vowel for consonant duration

DURATION						
PoA*Rate	FAST			SLOW		
Vowel	*df*	*F*	*P*	*df*	*F*	*P*
/a/	2, 2756.001	32.347	<001	2, 2756.027	13.122	<001
/u/	2, 2756.001	49.481	<001	2, 2756.978	50.074	<001

Table 3.45

Results of univariate tests for the effect of vowel across rate and PoA for consonant duration

DURATION						
Vowel*Rate	FAST			SLOW		
PoA	*df*	*F*	*P*	*df*	*F*	*P*
/b/	1, 2756.012	45.646	<001	1, 2755.983	194.647	<001
/d/	1, 2756.012	10.704	.001	1, 2755.983	3.339	.068
/g/	1, 2756.012	86.351	<001	1, 2755.983	137.425	<001

The significance shown in the results of univariate tests once more needs specific data on how different levels determine different consonant durations. As shown in Table 3.46, pairwise comparisons for the effect of rate show the detail of duration means and the corresponding significance. The differences observed in durations for /b/, /d/ and /g/ in the two speaking rates are significant in all cases. Thus, in this interaction, the strong effect of speaking rate is again confirmed, and it is illustrated graphically in Figure 3.14.

Table 3.46

Pairwise comparison results for the effect of rate across PoA and vowel for duration

DURATION						
Vowel*PoA				/b/	/d/	/g/
Rate				F. vs S.	F. vs S.	F. vs S.
		M	*SD*	*mean comparison (p)*		
/b/	FAST	40.459	17.375	<.001		
	SLOW	62.205	27.350			
/d/	FAST	33.151	13.889		<.001	
	SLOW	65.359	32.594			
/g/	FAST	32.003	11.465			<.001
	SLOW	58.773	27.163			

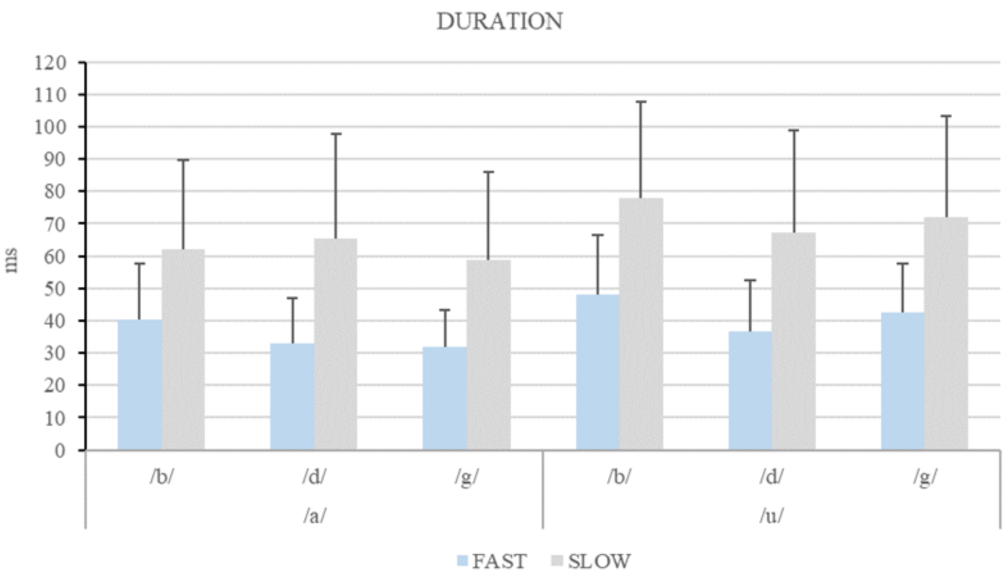
/a/

DURATION						
Vowel*PoA				/b/	/d/	/g/
Rate				F. vs S.	F. vs S.	F. vs S.
		M	*SD*	*mean comparison (p)*		
/b/	FAST	48.035	18.458	<.001		
	SLOW	77.969	29.778			
/d/	FAST	36.739	15.945		<.001	
	SLOW	67.246	31.736			
/g/	FAST	42.483	15.213			<.001
	SLOW	71.986	31.382			

/u/

Figure 3.14

Mean values for consonant duration for the effect of rate across PoA and vowel



In order to conclude this section, it should be pointed out that tests carried out for consonant duration need to be matched by intensity ratio tests. The results of these tests are reported in Section 3.4, and are expected to provide the necessary data to explain some facts shown in duration tests. Some duration results suggest that differences in consonant duration do not necessarily involve differences in constriction degrees, but these facts are expected to be related to the voiceless plosives included in the inventory and special cases with /d/ where lenited realizations are not expected. Intensity ratio data will help to discern how both acoustic facts go along in different constriction degrees and to provide data that contributes to explaining the multidimensionality of Spanish stop lenition.

3.4 Effects of speaking rate on intensity ratio

The mixed-models analysis run in this study also yielded the results for the effect of rate on the second main variable. As in the case of duration, intensity ratio results include the effect of speaking rate in interaction with the rest of factors in two-way, three-way and multiple interactions. As it is hypothesized in this study, intensity ratio results will provide a picture of the resulting lenited realizations and their constriction degrees, which are expected to go along with differences in duration. It is also assumed that due to the nature of Spanish plosive spirantization as a non-categorical phenomenon, constriction degrees will most probably bring about variability in these combined results. Chapter 4 will focus on how these results can be interpreted as patterns of consonant constriction degrees.

Fixed effects for factor interactions yielded significant differences in the intensity ratio value, as Table 3.47 displays. In order to provide evidence of the effects of individual factors in the interactions analysed, univariate tests will show the corresponding significance, while pairwise comparisons will show the differences across factor levels with the appropriate significance data. As it was arranged for duration results, the outcome obtained for intensity ratio will be displayed in the corresponding tables, and they will be supported by graphs for the effects of all factors in two-way interactions and for the effect of rate in three-way interactions.

Table 3.47

Fixed effects test results for two-way, three-way and multiple interaction for INT-R[7].

INTERACTION	DEPENDENT VARIABLE	*df*	*F*	*P*
rate * context	INT-R	10,2756.450	484.224	<.001
rate * PoA	INT-R	4,2756.006	11.941	<.001
rate * vowel	INT-R	2,2756.006	48.239	<.001
rate * context * PoA	INT-R	20,2756.004	5.690	<.001
rate * context * vowel	INT-R	10,2756.005	5.695	<.001
rate * PoA * vowel	INT-R	4,2756.001	17.529	<.001
rate * context * PoA * vowel	INT-R	71,2756.060	92.063	<.001

[7] Specific detail of significance for multiple-interaction results is not provided as it is not considered relevant for further evidence of the effect of time

3.4.1 Two-way interactions

As section 3.3 in the present chapter showed, two-way factor interactions yielded significant results for consonant duration differences. Now, it is necessary to observe how these differences are matched by intensity ratio results, although it can be assumed that some of the differences in durations may not be associated to lenition processes. These combined results for two-way interactions are expected to contribute to identifying lenition patterns that result from the effect of rate across the rest of factors. The results reported for two-way interactions will include univariate tests and pairwise comparisons for the effect of both factors. As it was shown for duration results, it is believed that this detail can provide evidence of the strength of the rate factor by comparison with the rest of factors in interaction. In addition, it can also help to observe how the effect of a given factor is altered as a function of rate.

3.4.1.1 Rate*context interaction

Intensity ratio results for the effect of the rate*content interaction appear as significant for both factors in the mixed-models analysis. In the same line as it appeared for duration, the effect of rate seems to have a powerful effect in interaction with context. Table 3.48 displays how all differences in intensity ratio are significant for rate across all contexts.

Table 3.48

Results of univariate tests for the effect of rate across context for INT-R

INT-R			
Rate*context	*df*	*F*	*P*
VCV	1,2756.006	162.388	<.001
VLCV	1,2756.006	54.568	<.001
VNCV	1,2756.006	23.550	<.001
VOV	1,2756.006	235.625	<.001
VRCV	1,2756.006	78.570	<.001
VSCV	1,2756.006	128.950	<.001

In order to show a bit more detail of the values corresponding to intensity ratio, Table 3.49 shows the means corresponding to the different intensity ratio values for fast and slow rates for all contents. This data may sound redundant for the resulting significance since only two factor levels are contrasted in this interaction. However, it shows the actual values, which are subsequently represented as a graph (see Figure 3.15). If we pair these results with the outcome for duration, it can be assumed that further observations are necessary to understand how the differences identified are associated to lenition processes, as analysed in Chapter 4.

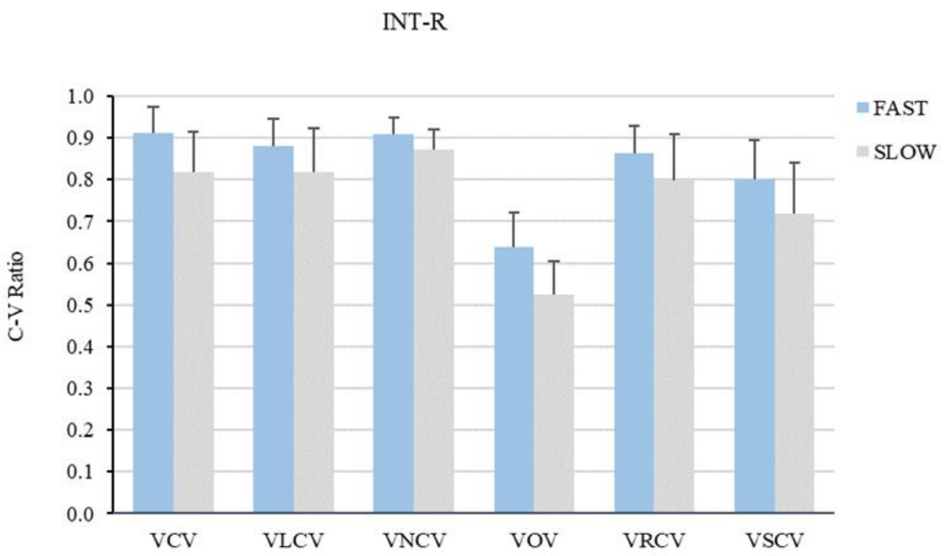
Table 3.49

Pairwise comparison results for the effect of rate across context for INT-R

INT-R										
Context					VCV	VLCV	VNCV	VOV	VRCV	VSCV
Rate	FAST		SLOW		FAST vs SLOW					
	M	*SD*	*M*	*SD*	*mean comparisons (p)*					
VCV	.912	.063	.818	.097	<.001					
VLCV	.882	.063	.819	.105		<.001				
VNCV	.908	.040	.873	.048			<.001			
VOV	.638	.083	.525	.080				<.001		
VRCV	.864	.065	.799	.112					<.001	
VSCV	.801	.094	.717	.124						<.001

Figure 3.15

Mean values for INT-R for the effect of rate across context



The context*rate interaction also yielded significant results for the effect of context across the two speaking rates. Table 3.50 shows the results of univariate tests, where all differences between contexts appear as significant for the two rates. Once more, it is necessary to look into pairwise comparisons to observe the specific significant differences between contexts. Pairwise comparison results show that differences in intensity ratio are also determined by specific comparisons between contexts. As shown in Table 3.51, VOV comparisons appear all significant, both for the fast and the slow rate, as it was also shown for consonant duration. In the case of the voiceless plosive, the difference in the intensity ratio value may be due to a sustained drop in absolute intensity in the occlusion section of the consonant at both rates. This result is also analysed in more detail in Chapter 4 by means of the corresponding spectrographic images.

Table 3.50

Results of univariate tests for the effect of context across rate for INT-R

INT-R			
Context*rate	*df*	*F*	*P*
FAST	5,2756.624	398.123	<.001
SLOW	5,2756.624	571.263	<.001

Table 3.51

Pairwise comparison results for the effect of context across rate for INT-R

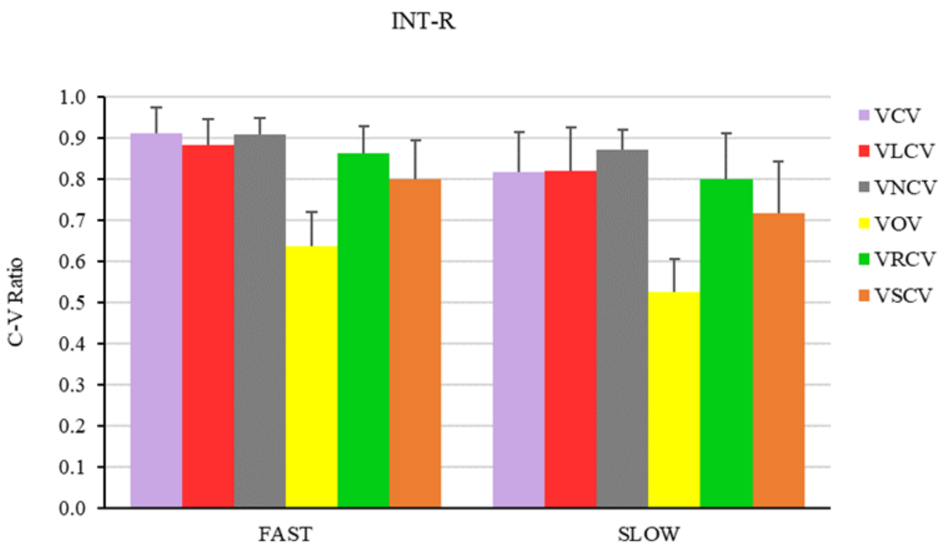
INT-R																
Rate	FAST								SLOW							
Context			VCV	VLCV	VNCV	VOV	VRCV	VSCV			VCV	VLCV	VNCV	VOV	VRCV	VSCV
	M	*SD*	*mean comparisons (p)*						*M*	*SD*	*mean comparisons (p)*					
VCV	.912	.063		.035	1	<.001	<.001	<.001	.818	.097		1	<.001	<.001	.116	<.001
VLCV	.882	.063			.155	<.001	.045	<.001	.819	.105			<.001	<.001	.016	<.001
VNCV	.908	.040				<.001	<.001	<.001	.873	.048				<.001	<.001	<.001
VOV	.638	.083					<.001	<.001	.525	.080					<.001	<.001
VRCV	.864	.065						<.001	.799	.112						<.001
VSCV	.801	.094							.717	.124						

It can also be observed that some significance results are conditioned by the effect of rate differently, with slightly more significance for the slow rate. Thus, comparisons between VNCV are all significant for the slow rate, while they are not significant when compared with VCV and VLCV for the fast rate. It is also remarkable that more significance is also shown for intensity ratio than for duration differences in the same two-way interaction comparisons. This can be understood as significant differences in constriction degrees, but qualitative observations is also necessary to interpret these results and how they are paired with duration data.

Some variability in intensity ratio results can also be observed for other contexts as they are analysed across rate. The comparison between VRCV and VLCV does not appear as significant for any of the two rates, but VRCV versus VCV appears as significant only at the slow rate. This could be due to the existence of a vocalic element that may be triggered by /r/ more prominently at a slow speaking rate. Spectrographic images will show the insertion of the vocalic element in the qualitative analysis in Chapter 4. Figure 3.16 displays these comparisons graphically.

Figure 3.16

Mean values for INT-R for the effect of context across rate



3.4.1.2 Rate*PoA interaction

As section 3.3 showed for duration, rate*PoA interaction results also provide data to analyse the strong effect of rate on lenited realizations. The results obtained for intensity ratio also show how both effects yielded significant differences when the interaction of effects is analysed. Table 3.52 shows significant differences in intensity ratio for the three points of articulation as a function of rate. This is further supported by pairwise comparisons and mean data in Table 3.53 and in Figure 3.17.

Table 3.52

Results of univariate tests for the effect of rate across PoA for INT-R

INT-R			
Rate*PoA	*df*	*F*	*P*
/b/	1,2756.006	196.770	<.001
/d/	1,2756.006	181.256	<.001
/g/	1,2756.006	229.038	<.001

Table 3.53

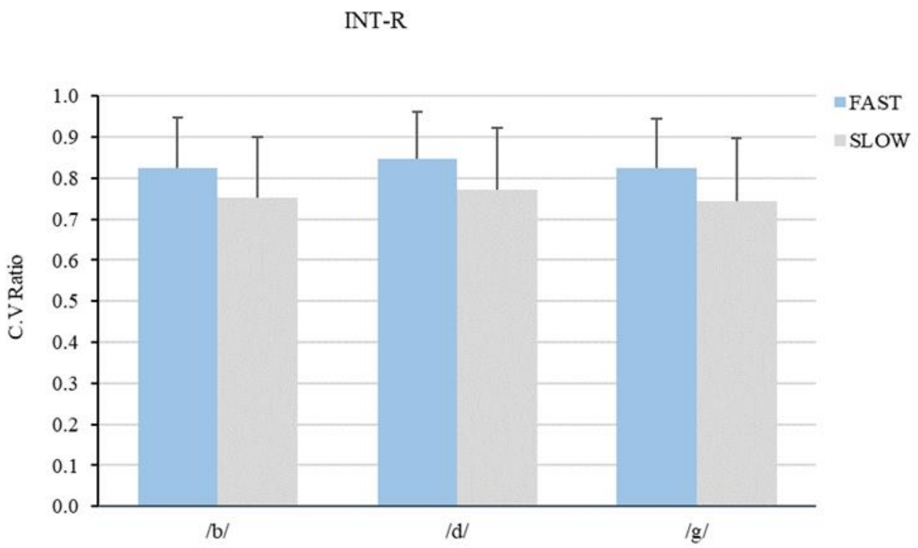
Pairwise comparison results for the effect of rate across PoA for INT-R

INT-R							
PoA					/b/	/d/	/g/
Rate	FAST		SLOW		FAST vs SLOW		
	M	*SD*	*M*	*SD*	*mean comparisons (p)*		
/b/	.826	.121	.753	.147	<.001		
/d/	.846	.116	.771	.152		<.001	
/g/	.825	.121	.743	.153			<.001

According to these results, it can be assumed that differences in constriction degree exist for /b/ /d/ and /g/ under the effect of rate. Again, data based on spectrographic images will provide some support to these assumptions and will help to interpret these results. For example, /d/ in the case of VLCV is not expected to undergo any lenition, while results showed significant differences in constriction degree across rates.

Figure 3.17

Mean values for INT-R for the effect of rate across PoA



Likewise, the effect of PoA on intensity ratio is also observed in the rate*PoA interaction, with significant differences shown by univariate tests. As Table 3.54 displays, the effect of PoA appears as significant across rates, but further observation for individual comparisons between the levels are necessary once more to discern the specific significance cases.

Table 3.54

Results of univariate tests for the effect of PoA across rate for INT-R

INT-R			
PoA*rate	*df*	*F*	*P*
FAST	2,2756.006	10.352	<.001
SLOW	2,2756.006	13.529	<.001

Table 3.55 focuses on pairwise comparisons, where significance variability is more apparent, and showing results which do not seem to pair the significance for duration differences completely. Intensity ratio differences seem to be more relevant for the fast rate (labial vs dental and dental vs velar), and significance is altered by the effect of rate, with only the dental-vs-velar comparison appearing as significant. It should be noted that these comparisons include the rest of factors, that is, context and

vowel, which have proved to yield variability on resulting lenited realizations. Thus, it is interesting to explore three-way interactions to discern how this significance is also associated to a particular context or vowel, when we know that rate has a clear effect for each of the consonants under study. Figure 3.18 represents the differences in intensity ratio between points of articulation as a function of rate.

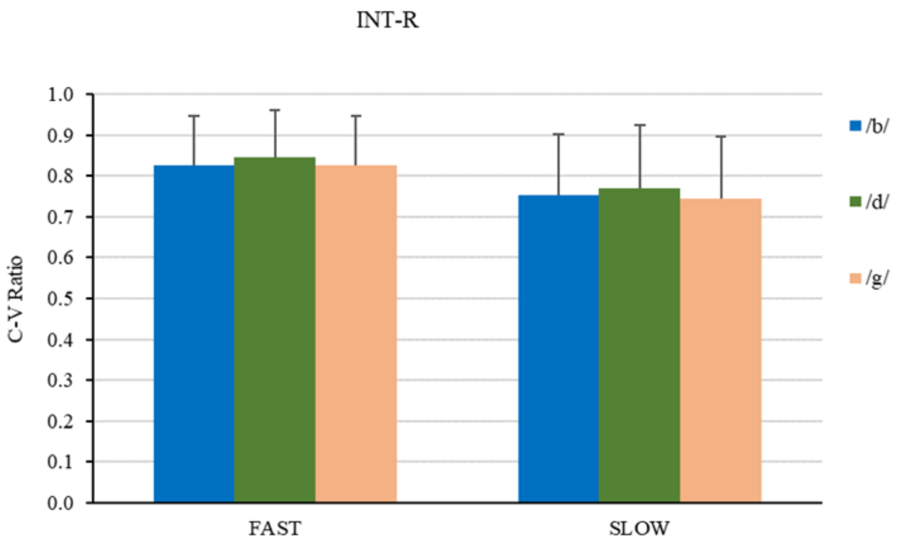
Table 3.55

Pairwise comparison results for the effect of PoA across rate for INT-R

INT-R										
Rate	FAST					SLOW				
PoA			/b/	/d/	/g/			/b/	/d/	/g/
	M	*SD*	*mean comparisons (p)*			*M*	*SD*	*mean comparisons (p)*		
/b/	.826	.121		<.001	1	.753	.147		.003	.192
/d/	.846	.116			<.001	.771	.152			<.001
/g/	.825	.121				.743	.153			

Figure 3.18

Mean values for INT-R for the effect of PoA across rate



3.4.1.3 Rate*vowel interaction

As it was reported for duration, two-way interactions also include the effect of rate and vowel, and the results for intensity ratio contribute to showing how speaking rate is a powerful condition. Table 3.56 shows that intensity ratio values are significantly different as a function of rate for both vowels, and Table 3.57 provides the detail of mean values for those comparisons. Figure 3.19 illustrates, in turn, these results. This effect of rate will be further discussed to analyse how these differences may correspond to different constriction degrees.

Table 3.56

Results of univariate tests for the effect of rate across vowel for INT-R

INT-R			
Rate*vowel	*df*	*F*	*P*
/a/	1,2756.006	247.137	<.001
/u/	1,2756.006	362.860	<.001

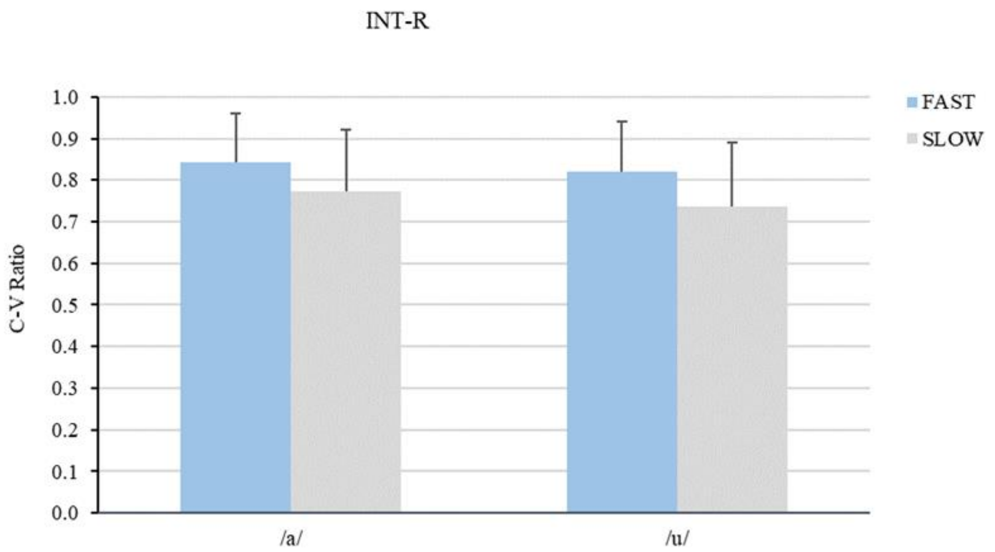
Table 3.57

Pairwise comparison results for the effect of rate across vowel for INT-R

INT-R						
Vowel					/a/	/u/
Rate	FAST		SLOW		FAST vs SLOW	
	M	*SD*	*M*	*SD*	*mean comparisons (p)*	
/a/	.843	.117	.774	.148	<.001	
/u/	.821	.121	.737	.152		<.001

Figure 3.19

Mean values for INT-R for the effect of rate across vowel



The last effect explored in two-way interactions involves the vowel factor across the fast and the slow rates. As Table 3.58 reveals, intensity ratio values are significantly different when the target consonants are flanked by the different vowels (/a/ and /u/) for both the fast and the slow rates. Pairwise comparisons are also included in Table 3.59 to show the actual mean values, while Figure 3.20 offers a graphical view of these results. Again, more specific interactions will shed some light on how other factors (context and PoA) may intervene in the differences observed for intensity ratio under the effect of vowel.

Table 3.58

Results of univariate tests for the effect of vowel across rate for INT-R

INT-R			
Vowel*rate	*df*	*F*	*P*
FAST	1,2756.006	25.735	<.001
SLOW	1,2756.006	70.743	<.001

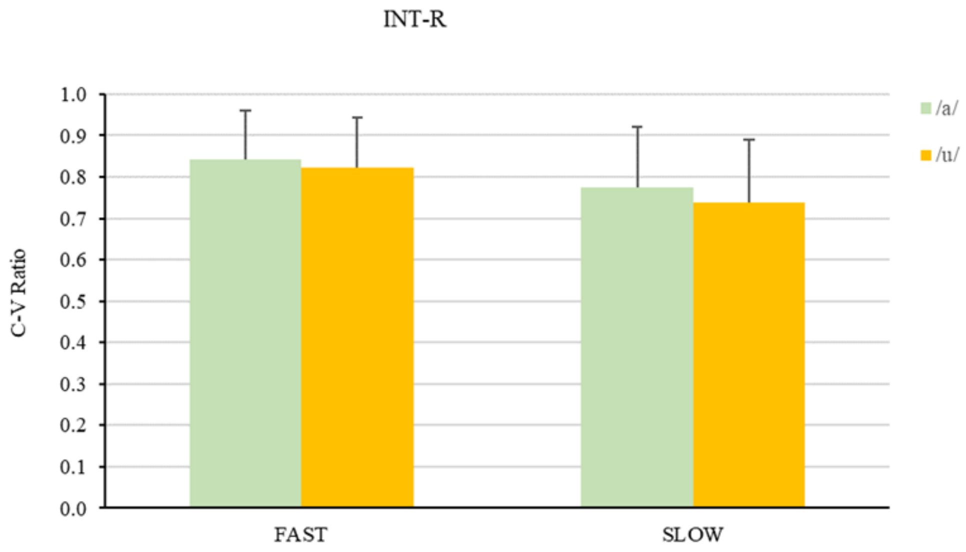
Table 3.59

Pairwise comparison results for the effect of vowel across rate for INT-R

INT-R						
Rate	FAST			SLOW		
Vowel			/a/ vs /u/			/a/ vs /u/
	M	*SD*	*mean comparisons (p)*	*M*	*SD*	*mean comparisons (p)*
/a/	.843	.117	<.001	.774	.148	<.001
/u/	.821	.121		.737	.152	

Figure 3.20

Mean values for INT-R for the effect of vowel across rate



As it has been pointed out throughout this section, in two-way interactions all factors seem to play a role in the production of lenited consonants according to intensity ratio, the selected acoustic parameter to analyse constriction degree. It has also been observed that this significance appears to show more variability under the effect of context, as different flanking segments may trigger different consonant constriction degrees. Variability also shows for the effect of PoA, as the different voiced consonants are compared. However, the effect of speaking rate appears to be consistent in all comparisons. One could argue that the powerful effect of rate across vowel and that of vowel across rate need more detail of how significance may be conditioned by other factor included, that is context and point of articulation. Three-way interactions can provide specific data and comparisons for different levels to work out how the significance identified and the strength of both effects is actually conditioned by these factors. These results can provide more evidence of the robust effect of time in the present study.

3.4.2 Three-way interactions

As the analysis of duration showed previously in this chapter, the behaviour of intensity ratio also needs to be explored in three-way factor interactions involving the effect of rate. The results shown focus on the effect of each factor in the corresponding comparisons across the other two factors in order to obtain more detailed data of the significance observed in two-way interactions. This applies to the results of univariate tests, while pairwise comparisons will be displayed only for more detail of the effect of rate in the interaction with the other factors. These data will help us discern how significance results for duration pair with those corresponding to intensity ratio and how qualitative observations are necessary to show the effect of factors on the production of different constriction degrees in the consonants under study. Again, the corresponding tables are included to display intensity ratio results for each factor, except for pairwise comparison tables, which are only included for rate (see Appendix E for the rest of three-way pairwise comparison tables). Graphs illustrating the corresponding effect involving rate are also shown for intensity ratio.

3.4.2.1 Rate*context*PoA interaction

Univariate tests for the rate*context*PoA interaction yielded different results for the effects of the different factors. In the case of rate, Table 3.60 shows that most comparisons between fast and slow are significant, except for the case of VLCV across /b/ and /d/, and the case of VNCV across /b/ and /g/. This means that these results pair duration results generally, with the exception of VLCV, for which fast-vs-slow comparisons yielded significant results in all cases. The case of VNCV also shows some variability, and rate only seems to alter intensity ratio in the case of homorganic /nd/ sequences. This is not assumed to go through any lenition process, so the qualitative observations will help to describe in more detail the resulting consonant in these cases.

Table 3.60

Results of univariate tests for the effect of rate across context and PoA for INT-R

INT-R									
Rate*PoA	/b/			/d/			/g/		
Context	*df*	*F*	*P*	*df*	*F*	*P*	*df*	*F*	*P*
VCV	1,2756.004	89.780	<001	1,2756.007	56.693	<001	1,2756.006	36.136	<001
VLCV	1,2756.998	6.093	.014	1,2756.000	5.428	.020	1,2756.002	73.000	<001
VNCV	1,2756.002	11.113	.001	1,2756.004	13.104	<001	1,2756.008	3.281	.070
VOV	1,2756.994	101.040	<001	1,2756.996	94.492	<001	1,2756.999	63.235	<001
VRCV	1,2756.000	13.294	<001	1,2756.002	19.273	<001	1,2756.006	63.577	<001
VSCV	1,2756.027	28.611	<001	1,2756.029	66.087	<001	1,2756.999	49.446	<001

Univariate test results for the effect of context also show some different significant data in comparison with duration results. As Table 3.61 shows, context appears as significant across rate and point of articulation, indicating that flanking segments play a role in this three-way interaction. However, in contrast to duration results, PoA does not seem to have a significant effect in this interaction with rate and context. Table 3.62 shows how the effect of PoA on intensity ratio is significant only for VCV in the fast rate and for VCLV in the slow rate.

Table 3.61

Results of univariate tests for the effect of context across rate and PoA for INT-R

INT-R									
Context*PoA	/b/			/d/			/g/		
Rate	*df*	*F*	*P*	*df*	*F*	*P*	*df*	*F*	*P*
FAST	5, 2756.237	143.898	<001	5, 2756.136	145.647	<001	5, 2756.136	150.955	<001
SLOW	5, 2756.237	213.831	<001	5, 2756.159	228.713	<001	5, 2756.129	194.491	<001

Table 3.62

Results of univariate tests for the effect of PoA across context and rate for INT-R

INT-R						
PoA*Rate	FAST			SLOW		
Context	*df*	*F*	*P*	*df*	*F*	*P*
VCV	2, 2756.008	9.707	<001	2, 2756.007	5.797	.003
VLCV	2, 2756.008	5.113	.006	2, 2756.006	36.402	<001
VNCV	2, 2756.008	2.008	.135	2, 2756.007	0.158	.854
VOV	2, 2756.008	5.869	.003	2, 2756.007	2.125	.120
VRCV	2, 2756.008	3.843	.022	2, 2756.007	5.738	.003
VSCV	2, 2756.008	2.953	.052	2, 2756.013	3.156	.043

As it was arranged for consonant duration, pairwise comparisons are also shown for the effect of rate, although only two levels are involved. Thus Table 3.63 shows the corresponding mean data for these comparisons, where intensity ratio is not significantly different in the case of VLCV for /b/ and /d/ and VNCV for /g/. However, the robust significance of rate effects across context and PoA is made apparent once more. Figure 3.21 illustrates all these comparisons graphically.

Table 3.63

Pairwise comparison results for the effect of rate across context and PoA for INT-R

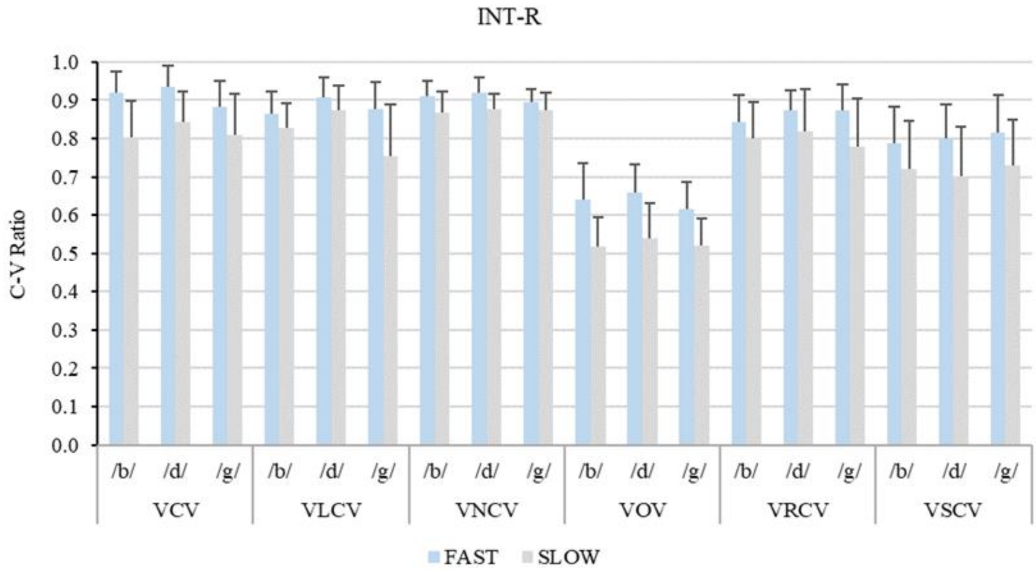
INT-R											
		VCV					VLCV				
Context*PoA				/b/	/d/	/g/			/b/	/d/	/g/
Rate				F. vs S.	F. vs S.	F. vs S.			F. vs S.	F. vs S.	F. vs S.
		M	*SD*	*mean comparisons (p)*			*M*	*SD*	*mean comparisons (p)*		
/b/	FAST	.920	.055	<.001			.863	.058	.014		
	SLOW	.804	.095				.828	.064			
/d/	FAST	.934	.054		<.001		.907	.053		.020	
	SLOW	.842	.080				.874	.065			
/g/	FAST	.882	.068			<.001	.875	.071			<.001
	SLOW	.809	.109				.755	.134			

INT-R											
		VNCV					VOV				
Context*PoA				/b/	/d/	/g/			/b/	/d/	/g/
Rate				F. vs S.	F. vs S.	F. vs S.			F. vs S.	F. vs S.	F. vs S.
		M	*SD*	*mean comparisons (p)*			*M*	*SD*	*mean comparisons (p)*		
/b/	FAST	.910	.040	.001			.639	.096	<.001		
	SLOW	.869	.055				.516	.077			
/d/	FAST	.920	.041		<.001		.658	.075		<.001	
	SLOW	.876	.040				.539	.090			
/g/	FAST	.895	.034			.070	.617	.071			<.001
	SLOW	.873	.047				.519	.071			

INT-R											
		VRCV					VSCV				
Context*PoA				/b/	/d/	/g/			/b/	/d/	/g/
Rate				F. vs S.	F. vs S.	F. vs S.			F. vs S.	F. vs S.	F. vs S.
		M	*SD*	*mean comparisons (p)*			*M*	*SD*	*mean comparisons (p)*		
/b/	FAST	.844	.070	<.001			.787	.095	<.001		
	SLOW	.800	.095				.721	.124			
/d/	FAST	.872	.054		<.001		.800	.089		<.001	
	SLOW	.819	.110				.700	.130			
/g/	FAST	.875	.066			<.001	.816	.096			<.001
	SLOW	.777	.126				.730	.118			

Figure 3.21

Mean values for INT-R for the effect of rate across context and PoA



3.4.2.2 Rate*context*vowel interaction

The three-way interaction involving rate, context and vowel can also provide more quantitative evidence of the strength of the rate factor. The results of univariate tests for the rate*context*vowel interaction show that the three factors have a major effect on consonant constriction degree, although some differences can be observed. The effect of rate is clearly powerful, as it is shown in Table 3.64, with only 2 values different from <.001 yet very close to it (VLCV and VNCV for /a/).

Table 3.64

Results of univariate tests for the effect of rate across context and vowel for INT-R

INT-R						
Rate*Vowel	/a/			/u/		
Context	*df*	*F*	*P*	*df*	*F*	*P*
VCV	1, 2756.030	104.041	<001	1, 2755.976	73.831	<001
VLCV	1, 2756.994	11.328	.001	1, 2755.996	56.672	<001
VNCV	1, 2756.030	10.618	.001	1, 2755.989	15.195	<001
VOV	1, 2756.004	150.000	<001	1, 2755.989	107.943	<001
VRCV	1, 2756.004	22.636	<001	1, 2756.001	69.125	<001
VSCV	1, 2756.041	40.547	<001	1, 2756.004	107.718	<001

Univariate tests also show significance for the effect of context and vowel in this three-way interaction. For the effect of context, differences in intensity ratio are significant by rate and vowel, as shown in Table 3.65, which can be expected as it was also the case of context for two-way interaction. Further details of the effect of context for three-way interactions are shown in Appendix E for pairwise comparison results, and they are also discussed in Chapter 4.

In addition, univariate tests reveal how the effect of vowel for intensity ratio is a bit weaker than for duration. VNCV, VOV, VRCV and VSCV seem to be less affected by the vowel factor than VLCV and VCV. At the same time, this effect also interacts with rate with different significant differences between /a/ and /u/ for fast and slow rates. This does not match durations results exactly, and an evaluation of results in the light of spectrographic images will help us observe those differences in constrictions degrees. Table 3.66 shows how intensity ratio is determined by the vowel factor across contexts and rates.

Table 3.65

Results of univariate tests for the effect of context across rate and vowel for INT-R

INT-R						
Context*Vowel	/a/			/u/		
Rate	*df*	*F*	*P*	*df*	*F*	*P*
FAST	5, 2756.336	214.673	<001	5, 2756.337	223.171	<001
SLOW	5, 2756.318	329.332	<001	5, 2756.337	298.827	<001

Table 3.66

Results of univariate tests for the effect of vowel across context and rate for INT-R

INT-R						
Vowel*Rate	FAST			SLOW		
Context	*df*	*F*	*P*	*df*	*F*	*P*
VCV	1, 2756.012	23.008	<001	1, 2755.987	10.170	.001
VLCV	1, 2755.992	12.362	<001	1, 2756.015	58.957	<001
VNCV	1, 2756.025	0.040	.841	1, 2756.004	0.706	.401
VOV	1, 2756.012	13.924	<001	1, 2756.017	3.510	.061
VRCV	1, 2755.999	1.965	.161	1, 2756.017	24.586	<001
VSCV	1, 2756.012	0.241	.624	1, 2756.000	12.393	<001

In addition to the results shown in univariate tests above, Table 3.67 provides pairwise comparisons to illustrate how speaking rate is mainly relevant when fast and slow realizations are compared across context and vowel. The effect of rate is clearly strong in comparison with the effect of vowel in this three-way interaction and it seems to play a role in intensity ratio results, which indicates that a lenited realization may be involved. Figure 3.22 below also illustrates the differences in intensity ratio across rates, vowels and contexts.

Table 3.67

Pairwise comparison results for the effect of rate across context and vowel for INT-R

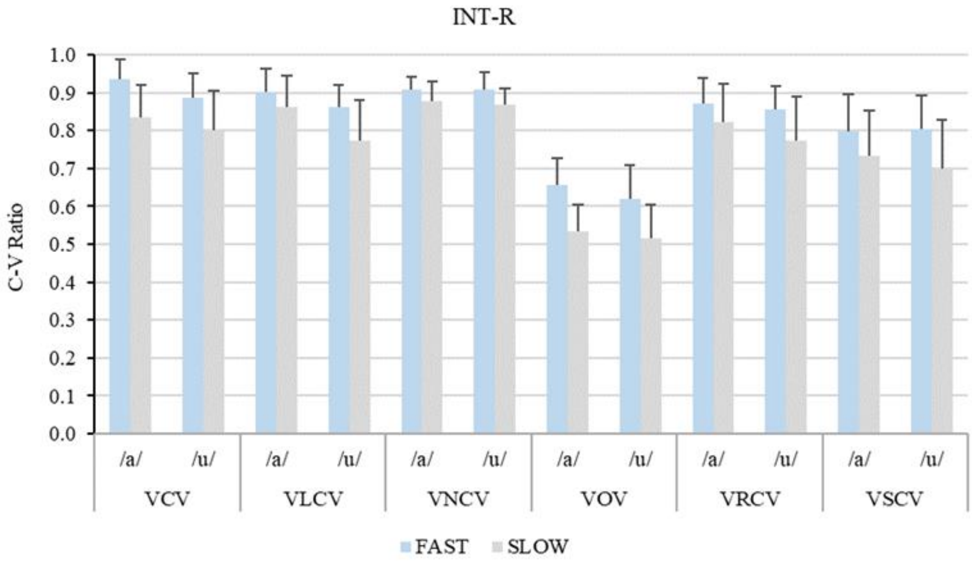
INT-R									
			VCV				VLCV		
Context*Vowel				/a/	/u/			/a/	/u/
Rate				FAST vs SLOW				FAST vs SLOW	
		M	*SD*	*mean comparisons (p)*		*M*	*SD*	*mean comparisons (p)*	
/a/	FAST	.936	.053	<.001		.902	.060	.001	
	SLOW	.834	.087			.863	.083		
/u/	FAST	.888	.064		<.001	.862	.060		<.001
	SLOW	.802	.103			.775	.107		

			VNCV				VOV		
Context*Vowel				/a/	/u/			/a/	/u/
Rate				FAST vs SLOW				FAST vs SLOW	
		M	*SD*	*mean comparisons (p)*		*M*	*SD*	*mean comparisons (p)*	
/a/	FAST	.909	.032	.001		.657	.071	<.001	
	SLOW	.877	.053			.534	.071		
/u/	FAST	.907	.046		<.001	.619	.090		<.001
	SLOW	.868	.042			.516	.088		

INT-R									
			VRCV				VSCV		
Context*Vowel				/a/	/u/			/a/	/u/
Rate				FAST vs SLOW				FAST vs SLOW	
		M	*SD*	*mean comparisons (p)*		*M*	*SD*	*mean comparisons (p)*	
/a/	FAST	.871	.067	<.001		.798	.099	<.001	
	SLOW	.823	.101			.735	.118		
/u/	FAST	.857	.062		<.001	.803	.088		<.001
	SLOW	.774	.116			.700	.129		

Figure 3.22

Mean values for INT-R for the effect of rate across context and vowel



3.4.2.3 Rate*PoA*vowel interaction

The last three-way interaction involving rate shows that the three factors have an effect on intensity ratio. The results of univariate tests reveal that the rate factor has a robust effect on intensity ratio when analysed across PoA and vowel. As Table 3.68 shows, intensity ratio values are significantly different for /b/, /d/ and /g/ as a function of rate, for both vowels (/a/ and /u/). In the same line, the effect of point of articulation seems to affect intensity ratio significantly, which pairs the results for consonant duration (Table 3.69). However, as it was observed for duration results, the effect of vowel seems to be weaker for intensity ratio as well. As displayed in Table 3.70, intensity ratio values are also significantly conditioned by the effect of vowel across the two rates, and two of the consonants (/b/ and /g/). In the case of /d/, intensity ratio values are not significantly different across vowels in either rate, which again matches the trend observed for duration values.

Table 3.68

Results of univariate tests for the effect of rate across PoA and vowel for INT-R

INT-R						
Rate*Vowel	/a/			/u/		
PoA	*df*	*F*	*P*	*df*	*F*	*P*
/b/	1, 2756.048	56.144	<001	1, 2755.981	145.140	<001
/d/	1, 2756.073	96.802	<001	1, 2755.981	109.728	<001
/g/	1, 2756.021	115.473	<001	1, 2755.983	147.351	<001

Table 3.69

Results of univariate tests for the effect of PoA across rate and vowel for INT-R

INT-R						
PoA*Rate	FAST			SLOW		
Vowel	*df*	*F*	*P*	*df*	*F*	*P*
/a/	2, 2756.008	21.509	<001	2, 2756.022	7.907	<001
/u/	2, 2756.008	14.741	<001	2, 2756.016	21.419	<001

Table 3.70

Results of univariate tests for the effect of vowel across rate and PoA for INT-R

INT-R						
Vowel*Rate	FAST			SLOW		
PoA	*df*	*F*	*P*	*df*	*F*	*P*
/b/	1, 2756.013	5.187	<001	1, 2755.994	5.225	<001
/d/	1, 2756.013	19.176	.023	1, 2756.019	25.167	.022
/g/	1, 2756.013	54.223	<001	1, 2755.986	76.726	<001

The significance shown in the results of univariate tests is once more supported by specific pairwise comparison data. As shown in Table 3.71, pairwise comparisons for the effect of rate show the detail of intensity ratio means and the corresponding significance. The differences observed in intensity ratio for /b/, /d/ and /g/ in the two speaking rates are significant in all cases, and they are illustrated graphically in Figure 3.23, providing more evidence of the relevant effect of speaking rate in three-way interaction.

Table 3.71

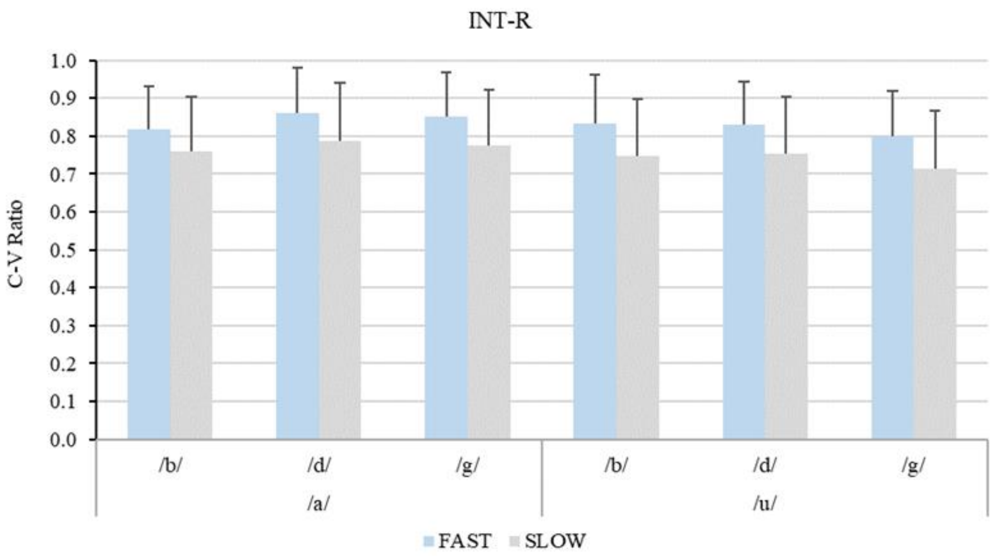
Pairwise comparison results for the effect of rate across PoA and vowel for INT-R

/a/						
Vowel*PoA				/b/	/d/	/g/
Rate				F. vs S.	F. vs S.	F. vs S.
		M	*SD*	*mean comparison (p)*		
/b/	FAST	.817	.113	<.001		
	SLOW	.760	.144			
/d/	FAST	.862	.118		<.001	
	SLOW	.788	.153			
/g/	FAST	.851	.116			<.001
	SLOW	.774	.147			

INT-R						
/u/						
Vowel*PoA				/b/	/d/	/g/
Rate				F. vs S.	F. vs S.	F. vs S.
		M	*SD*	*mean comparison (p)*		
/b/	FAST	.834	.127	<.001		
	SLOW	.746	.151			
/d/	FAST	.831	.112		<.001	
	SLOW	.754	.150			
/g/	FAST	.798	.120			<.001
	SLOW	.713	.153			

Figure 3.23

Mean values for INT-R for the effect of rate across PoA and vowel



In order to conclude this section and chapter, it is worth noticing that statistical results based on the mixed-models analysis have provided the necessary grounds to validate some of the procedures implemented in this study, and have also provided evidence to support the assumed hypotheses in the present work. Firstly, it has been shown that replication does not have an effect on statistical results in this type of experiment, which validates the laboratory procedure based on repetitions by the same subject. Another fact that the statistical analysis accounts for is the random nature of the subject factor. The mixed-models analysis has allowed to integrate the subject factor as a random effect, with the corresponding assumption that the subjects selected for the experiment are replicating the facts that could be expected of a different, wider sample population selected.

The quantitative data reported in this chapter has provided evidence of the strong effect of speaking rate on the acoustic cues and values that define the production of lenited voiced plosives in Castilian Spanish. Thus, the fast speaking rate exhibits shorter consonant durations and intensity ratio values that may correspond to lenited realizations. It has also been shown that duration and intensity ratio values generally match for fast vs slow comparisons, and they go along quite consistently in the different analysis carried (main effects, two-way and three-way interactions). However, some variability has been observed in specific comparisons between levels concerning context and PoA, and consonant duration differences do not match intensity ratio differences and vice-versa. At this stage this is assumed to be showing the variability that also underlies the non-categorical nature of stop lenition phenomenon in Spanish, as reported previously.

Finally, although it is assumed that the statistical results have provided evidence of the hypothesized postulations in this study, these results need to be evaluated to discern to what extent the differences observed in consonant duration and intensity ratio correspond to lenited realizations, and how other coarticulation phenomena may also occur. This is clearly the case of VNCV, where voiced plosives are not expected to undergo lenition in contact with a homorganic flanking nasal. It is also the case of VOV, which as a voiceless plosive is expected to undergo less lenition, if any is possible under the effect of the factors in the present study. These facts, together with the variability also shown by quantitative data for spirantized realizations, will be discussed in Chapter 4.

Chapter 4 Discussion and concluding remarks

The results presented in Chapter 3 showed a raw picture of some facts that contribute to describing the lenition processes of voiced plosives in Castilian Spanish. Throughout the chapter, evidence was provided that supports the main hypotheses stated in this work on the role of time in the phenomenon. The present chapter is intended to provide a thorough appraisal of the quantitative results in the light of the hypotheses introduced in Chapter 1. For that purpose, section 4.1 presents a general evaluation of the results reported in Chapter 3, supported by relevant acoustic features of the corresponding stop realizations observed in the spectrographic images. According to this evaluation of results, section 4.2 will look into some constriction degree patterns identified that can be associated to the effect of time shown in the results. Section 4.3 will focus on validating the hypotheses stated previously in this work and it will explain how the evidence provided supports the main assumptions. Section 4.4, in turn, will review the phenomenon in the light of articulatory phonology premises, which is assumed to account for the phonetic processes observed, as time becomes a relevant feature in lenited realizations. To conclude, some final remarks will highlight the main facts brought into light as a result of the research presented in this dissertation.

4.1 Evaluation of results

An evaluation of results in the present study calls for an appraisal of quantitative results and statistical data yielded in the outcome of the mixed-models analyses performed, which include the two dependent variables selected as acoustic cues of consonant lenition. Regarding consonant duration, some previous accounts on Spanish spirantization (Martínez-Celdrán, 1984, 1991b, 2013) emphasized that consonant durations corresponding to approximant realizations are shorter than closer realizations of /b, d, g/, in an attempt to describe their acoustic features. It is important to point out that duration measurements in the present study were not intended to provide absolute durations of voiced plosive realizations. Instead, consonant duration values are intended to show relative differences between different consonant realizations, determined by selected conditions, among which speaking rate stands out as the focus of this study. In the same lines, the evaluation of quantitative results for intensity ratio is also the focus of the observations in the present chapter, since statistical results showed some general trends about potentially lenited realizations based on intensity ratio. As an acoustic cue of consonant constriction degree, higher values (closer to 1) could represent more lenited consonants, while lower values (closer to 0) could be instances of closer realizations. Thus, an evaluation of statistical results considering the images provided by the acoustic analysis can shed some light on how factors have an effect on consonant constriction degrees, coarticulation phenomena, and the complex nature of lenited realizations.

The general picture drawn by the statistical results in this study reveals that rate has a significant effect on consonant constriction degree, with significant differences in consonant durations and intensity ratio values between fast and slow rates for most of the cases. Although the main focus of the evaluation lies on observing the differences triggered by speaking rates, the rest of factors are also taken into consideration, especially in how they interact with fast and slow rates. More specifically, contextual factors have been the focus of attention in previous studies, as shown in Chapter 1, so the effects of context and vowel, as contextual factors in the present study, are also evaluated considering the corresponding spectrographic images.

4.1.1 Main effects and lenition phenomena: duration and intensity ratio

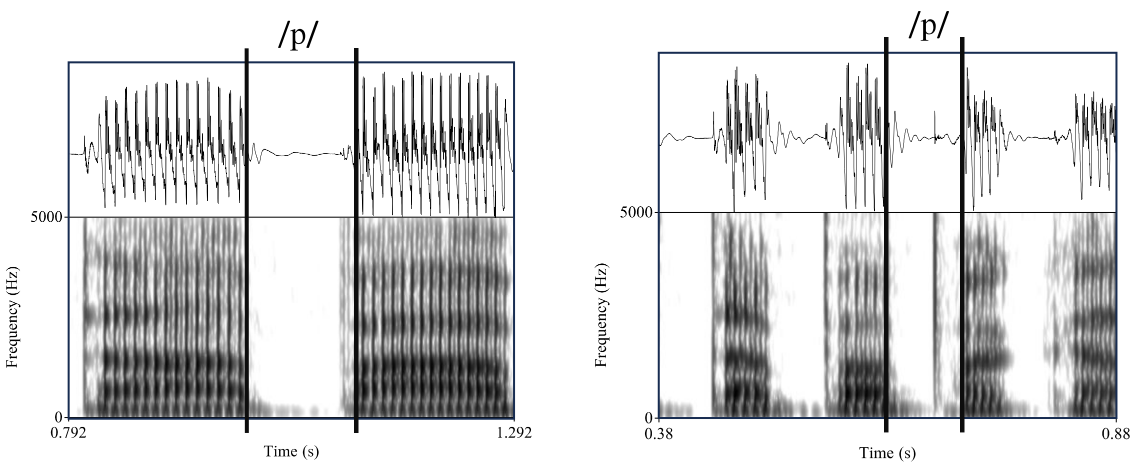
First of all, results for main effects showed significant differences in consonant duration as a function of speaking rate. Even though main effects include the rest of conditions (context, vowel and PoA), these results provided a rough picture of the potential effect of speaking rate (and the rest of factors) on the selected acoustic cues of consonant lenition. In the case of speaking rate as a main effect, the differences between fast and slow realizations yielded significant differences between what could be considered long and short realizations (given the significance exhibited). In this general analysis, the shortest realizations (in the fast-rate group) correspond to cases of lenited consonants, or consonants in homorganic sequences with flanking nasals, where coarticulation effects play an important role. In contrast, the longest consonants (in the slow-rate group) correspond to instances of voiceless plosives (/p, t, k/).

Leaving values at either end aside, main effects can shed some light on a general comparison between fast and slow rates and the behaviour of consonant duration and intensity ratio values. In fact, it should be noticed that the fast rate in the sample presented in this study represents the usual, casual speaking rate. Thus, as shown in the discussion on interactions below, fast realizations exhibit lenition patterns in the line observed in previous studies, where intervocalic consonants are most lenited (Hualde, Shosted & Scarpace, 2011, for /d/; Martínez-Celdrán, 2013; Martínez-Celdrán & Regueira, 2008, for Galician; Recasens, 2015, for Catalan, for example). Martínez Celdrán (2013), in an attempt to describe the features of "aproximantes espirantizadas" in casual, conversational style showed that a high percentage of intervocalic voiced plosives were realized as lenited consonants. Although showing occurrence frequency is not the focus of the present study, it can be seen that shorter consonant durations correspond to the VCV context.

In contrast, as we observe the results for the two different rates, main effects show that the bulk of realizations in the slow utterances are significantly longer. As shown in Chapter 3, these significant differences in duration cannot be assumed to indicate spirantized versus close realizations since they include context conditions where spirantization would not be expected, that is after /l/ (VLCV) (for /d/), after nasal (VNCV) and the case of voiceless plosive (VOV). In order to illustrate how these differences are due to features other than lenition, two voiceless plosive realizations for /p/ are shown in Figure 4.1, for fast and slow realizations, respectively. Fast /p/ is significantly shorter than slow /p/. The images show that longer durations are the result of a sustained occlusion in the case of the slow realization, with no periodic energy during the release.

Figure 4.1

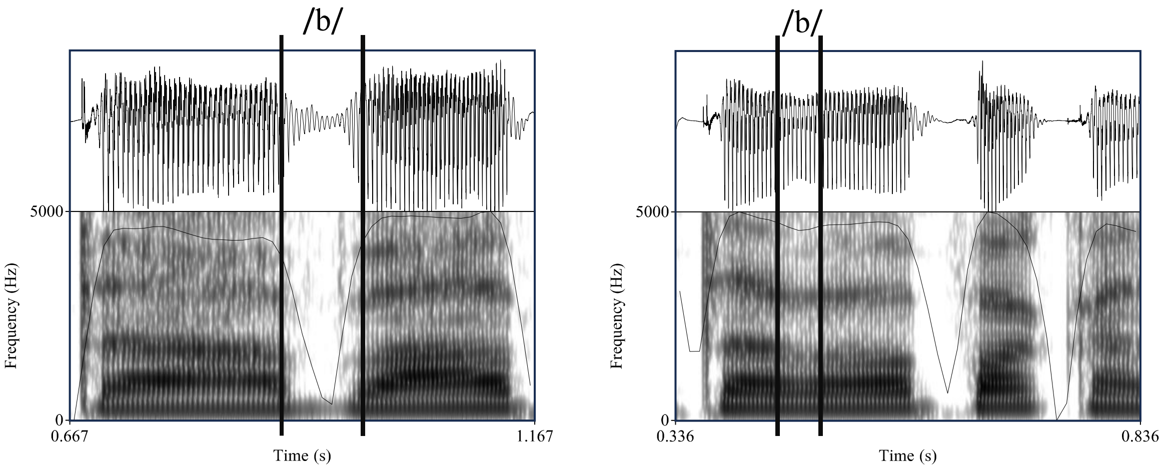
Spectrographic images of slow (left) vs fast (right) /p/ in "tapapa"



Likewise, intensity ratio results for main effects also showed significant differences between speaking rates, which indicated that fast realizations exhibited higher values. In the same line as duration results, higher values correspond to the fast-rate group and for intervocalic realizations, while lower values correspond to the slow-rate group and voiceless plosives. These intensity ratio results can be generally interpreted as more lenited versus closer realizations in the whole sample, as they also match the significance observed in duration results according to the hypothesized outcome: slow rate favours closer realizations. In fact, as depicted in Figure 4.2, spectrographic images for fast and slow intervocalic realizations show a clear case of consonant lenition in the fast realization versus a close realization in the slow rate. Fast /b/ (or /β̞/) exhibits high intensity pulses, clear formants along all the frequencies that show a clear transition towards flanking sounds. In contrast, slow /b/ shows a clear drop in energy and a visible release burst.

Figure 4.2

Spectrographic images of slow (left) vs fast (right) /b/ in "tabapa" (VCV)



Main effects also provided interesting data for the effect of context, since these results could guide further observations in the case of two-way and three-way interactions. It was observed that the effect of context is robust for duration, even though the rest of conditions are again included in these results, and even when interaction data is necessary to draw more sustained conclusions. These results are aligned with previous findings (Martínez-Celdran, 2013; Recasens, 2015, for Catalan;

Simonet et al., 2012 for /d/), where flanking segments are reported to strongly determine different outcomes of voiced plosive realizations. As suggested in these studies, there is a clear effect of context, yielding observed variability in the contexts that have been recognised as those commonly triggering the occurrence of spirantized realizations.

More specifically, in the results for main effects displayed in Chapter 3, durations show significant differences in some comparisons involving contexts while they appear as non-significant in other cases. The target voiced plosives flanked by nasals (VNCV) and voiceless plosives (VOV) appear as significantly different when they are compared to the rest of contexts. Even when all the rest of factors are included in these results, it is relevant to mention that consonants are shorter when flanked by nasals due to the effect of gestural blending, while voiceless plosive realizations are longer than the rest of realizations. However, in some of the comparisons, durations are not significantly different across contexts. Durations for VCV are not different from VRCV and VSCV, as it could be expected according to previous findings. It is assumed, though, that for main effects, speaking rate is playing an important role, where realizations for the slow rate could introduce variability. Therefore, an evaluation of interactions (below) will provide more data to draw conclusions for the effect of context.

Intensity ratio differences shown for the effect of contexts in main effects results are more robust than duration differences across contexts, probably due to differences in constriction degree patterning for different contexts. But this difference may not be based on spirantization phenomena exclusively. This is the case of VNCV vs VOV, for instance, where intensity ratio is also significantly different. Different intensity ratio values in this comparison can be due to a steady decreased intensity for VOV (as shown in Figure 4.1), as opposed to sustained nasality in the case of VNCV. In another interesting case, intensity ratio differences are not significant in the comparison between VCV and VLCV. As suggested in Recasens (2015), the passage of airflow through wide oral openings in the case of /l/ requires less oral pressure, favouring less constricted realizations of /b, d, g/ after the lateral. An evaluation of results for factor interactions will allow to observe any constriction patterns across factor levels that can help to clarify the nature of these differences.

An evaluation of main effects results also includes the effect of vowel as a contextual factor. Similarly, flanking vowel has an effect on consonant duration, and results show that target consonants are significantly longer when flanked by /u/. This general result does not seem to match previous findings that studied the behavior of /b/ and /g/ (Ortega-Llebaria, 2004), where it was observed that realizations of /g/ were more lenited when flanked by /u/ than by /a/. If consonant duration is interpreted as a potential cue of consonant lenition, these results are showing the opposite. Indeed, flanking /a/ yields significantly shorter consonant durations and higher intensity ratio values, indicating more lenited realizations. The evaluation of factor interaction results will shed more light on the effect of vowel, although general trends suggested in main effects results turn out to provide a valuable, general picture.

As the final factor included in this evaluation of main effects results, the effect of PoA also provides some interesting data. While it is again a fact that all factors and their corresponding levels are included, /b/ appears as significantly longer than /d/ or /g/, whereas consonant duration differences between /d/ and /g/ appear as non-significant. At this point, this result suggests that there may be some significant differences between resulting realizations of lenition processes in terms of point of articulation, as previous findings have shown (Carrasco et al., 2012; Ortega-Llebaria, 2004; Recasens, 2015). However, these results include both speaking rates, and more detail is necessary to observe differences between /b/, /d/ and /g/. Intensity ratio results for the effect of PoA do not seem to match duration results completely. In this case, although /b/ appears as more constricted, differences are not significant when compared with /g/. Nevertheless, differences in intensity ratio are significant when /d/ is involved (in comparisons with both /b/ and /g/), with /d/ appearing as more lenited, which can be supported by further insights into factor interaction in this evaluation of results.

In order to discern how differences in consonant duration and intensity ratio are associated to weakening processes, it is necessary to observe two-way and three-way interactions. As mentioned above, the general trend is a robust effect of rate, which appeared as yielding significant differences in most of the comparisons in the statistical results. In the interaction between speaking rate and other factors, it was observed that rate yielded significant differences both in consonant duration and intensity ratio, which can be assumed to be associated with more consonant lenition for shorter realizations. The discussion in 4.1.2 and 4.1.3 below explains how these results can be interpreted in view of the features displayed in spectrographic images.

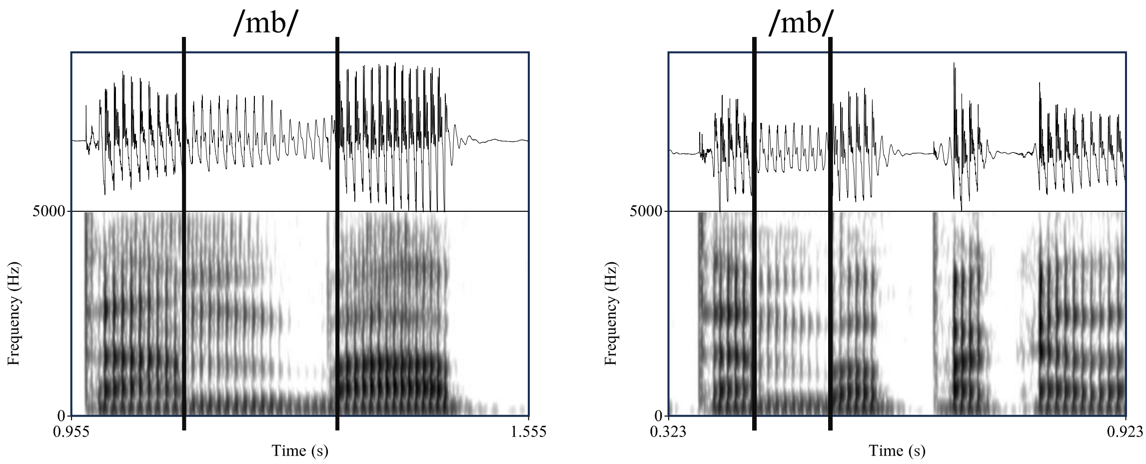
4.1.2. Two-way interaction and lenition phenomena: duration and intensity ratio

Two-way and three-way interaction results provide the necessary degree of detail to evaluate consonant lenition under the conditions selected in this study. As shown in Chapter 3, results involving rate include the following two-way interactions: rate*context, rate*PoA, rate*vowel. Some results provided by the statistical analysis follow similar trends identified for main effects, but the evaluation of the significance observed for those interactions, coupled with an examination of the features shown in spectrographic images, aims to account for the observed variability. Moreover, while a thorough examination of the effect of all factors is not the primary focus of this study, the observed trends will be discussed.

As shown in the presentation of the results, the effect of rate is clearly maintained in two-way and three-way interactions, and its interaction with context levels allows to observe how rate determines differences and variability across contexts. Both duration an intensity ratio values are significantly different for slow and fast rate for all the contexts. By observing the features in the corresponding spectrographic images, it can be confirmed that the differences between fast and slow for VNCV and VOV are based on factors other than spirantization phenomena in both rate groups. VNCV was initially considered a control context (traditionally considered unaffected by lenition processes) to observe how homorganic sequences for /b/, /d/ and /g/ behave when time is a variable in the experimental procedure. Both consonant duration and intensity ratio differences between fast and slow realizations for VNCV are significant, thus showing some effect of time. As suggested in Chapter 3, in spite of coarticulation phenomena due to homorganic tongue positions, blending decreases and both sounds are more clearly identified as duration increases. Figure 4.3 shows an instance of slow and fast realizations of VNCV. It can be observed that in the slow sequence, homorganicity causes extended nasality throughout the utterance, but coarticulation effects are not as strong as in the fast sequence. This can be interpreted as different degrees of coarticulation effects determined by time, which turn out to be significant for both acoustic cues of consonant constriction.

Figure 4.3

Spectrographic images of slow (left) and fast (right) "tambapa"



Interestingly enough, with respect to nasals, Honorof (2003) finds that in Castilian Spanish, /n/ is spirantized (de-occlusivized) in various environments as a function of speaking rate, where intervocalic /n/ is less tightly constricted. Based on his findings, he suggests that this de-occlusivization of /n/ is probably blocked in the same environment in which spirantization is blocked, establishing a parallelism between nasal de-occlusivization and spirantization since both can be understood as cases of gestural reduction. According to his predictions, it can be assumed that in VNCV contexts there is no voiced plosive lenition, and differences in duration and intensity ratio between fast and slow realizations may be caused by less relevant effects of coarticulation determined by time.

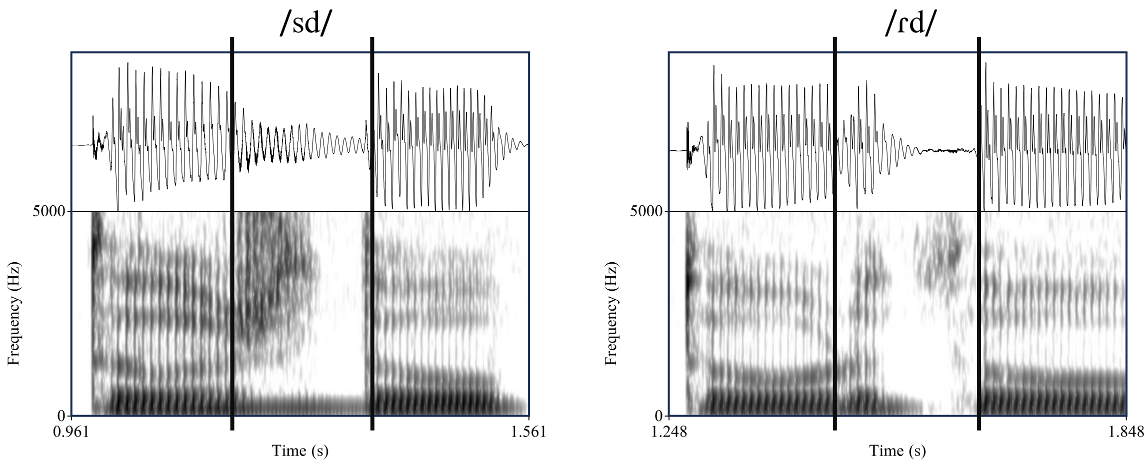
As mentioned above, the case of VOV also calls for an evaluation since consonant duration and intensity ratio values are significantly different between the two speaking rates. As shown in Figure 4.1, the difference is generally due to a longer occlusion in the slow rate, where intensity values also fall considerably (as mentioned above). In these cases, both realizations are instances of voiceless plosives for the three consonants (/b, d, g/). However, in the fast-rate group, voicing may surface randomly in a few cases, especially in the case of /k/, which is aligned with previous findings for the behaviour of voiceless plosives in Castilian Spanish. A number of studies have reported voiceless stop voicing in different conditions, especially in spontaneous speech and intervocalic position (Machuca, 1997; Hualde, Simonet & Nadeu, 2011, Romero et al, 2007; Hualde & Zhang, 2023). The cases identified in this study are instances of intervocalic position, since it is the only context included. No voicing has been observed in the slow-rate group. Instead, in longer realizations, the occlusion is extended and a clearer burst appears. Further observation of the occurrence of voiceless plosives is not considered to be the focus of this evaluation of results.

The rest of contexts, which are known to favour lenition, have shown to trigger different behaviours of voiced plosive consonants as a function of rate. Two-way interactions show that, again, consonant durations are significantly different as a function of rate for all contexts. Besides being significantly shorter, VCV, VLCV, VRCV and VSCV also appear as significantly less constricted in slow realizations, in the light of intensity ratio results. These results provide clear evidence of the role of time for both acoustic cues of consonant lenition, which is supported by the features displayed in the spectrographic images of these realizations. Figure 4.2 above illustrated the difference between fast and slow intervocalic (VCV) realizations, where differences in formant structure and sonority could be observed. The image for “fast /b/” shows intense glottal pulses and a clear formant transition to /a/, while the image for “slow /b/” shows a sonority bar, above which no formants can be distinguished.

However, the effect of rate, though always significant, may encourage different resulting realizations for VSCV and VRCV sequences in the slow-rate group (as compared to the fast rate). While features of more lenited realizations are observed in fast utterances, slow realizations seem to favour the occurrence of more constricted consonants in the case of VSCV, and instances of frication noise in VRCV. Figure 4.4 shows and example of a close realization of “tusdupu” and “turdupu” in the slow-rate group. Both realizations (closure for “tusdupu” and frication noise for “turdupu”) suggest that longer durations may result in the necessary time and condition to achieve the target closure for the voiced plosive consonant, or to create air turbulence more clearly than in the fast-rate group. These results would reinforce the findings in Romero, 1995, where evidence shows that consonant duration is responsible for the differences between Andalusian Spanish approximants and fricatives. Frication noise in “turdupu” below can surface as a consequence of devoting more time to produce it.

Figure 4.4

Spectrographic images of slow /d/ in "tusdupu" (left) and "turdupu" (right)



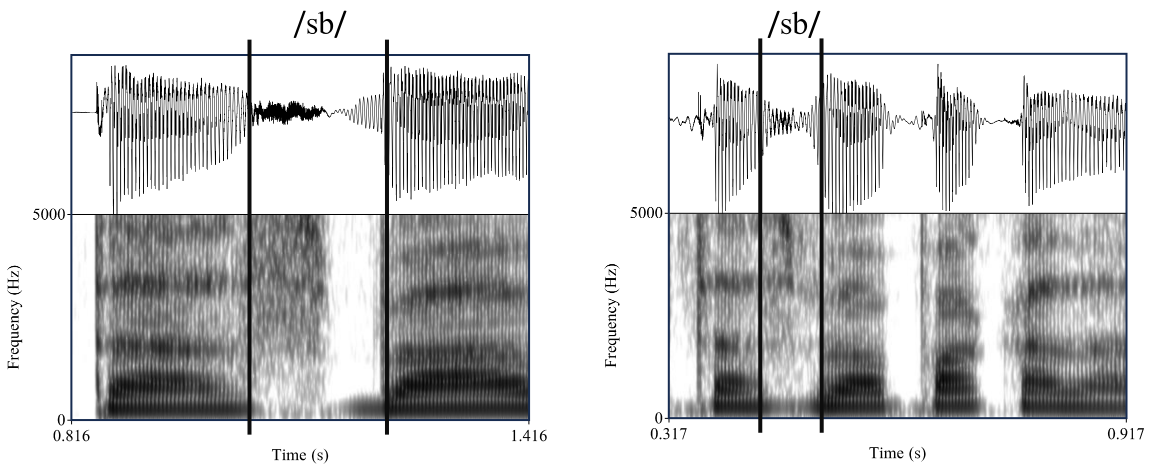
In order to elaborate on this evaluation of two-way interactions, besides observing the effect of time, it is also interesting to delve into the effect of contextual factors as shown in spectrographic images. It is worth noting that consonant durations are not significantly different in any comparisons between VCV, VLCV and VRCV and VSCV in the fast-rate group, which suggests that lenition patterns may be quite similar. However, the same comparisons result in more significant differences when intensity ratios are compared, and intervocalic positions (VCV) seems to result in more consonant lenition than VRCV and VSCV, according to the significance exhibited.

In the case of the slow rate, comparisons between contexts yield slightly different results. VRCV does not appear to be different from VCV, either for duration or intensity ratio values. The presence of a vocalic element (svarabhakti element) probably plays a role in the comparison between VCV and VRCV in the slow-rate group since it is more apparent than in the fast-rate group. This results in similar behaviour for VCV and VRCV, with the possibility of more open realizations of /b, d, g/ favoured by the appearance of the vocalic element in the slow-rate group. Thus, leaving aside VLCV, which, except for /d/, seems to trigger similar constriction degrees as VCV and VRCV, the rest of comparisons between these contexts appear as significantly different. In most cases, these differences are due to closer realizations also inside the slow-rate group. This is the case of significant differences between VCV and VSCV, with the occurrence of more constricted realizations for VSCV.

The case of VSCV also deserves special comments. According to Recasens (2015) for Catalan, voicing and lenition could be less common after fricatives than after sonorants (/l/ and /r/). Among the group that is assumed to undergo lenition, VSCV appears to have values for less lenited realizations than the rest of contexts. In the case of intensity ratio, VSCV has the lowest value in this group both for the fast and the slow rate, yielding significant differences in the comparisons with the rest of contexts. As mentioned above, consonant duration behaves differently in this case, since differences are not significant in comparisons between VCV, VRCV and VSCV in any case. However, these differences in intensity ratio between VSCV and the rest of contexts can be paired by other acoustic features corresponding to differences between more lenited and closer realizations in both speaking rates, in the line of differences observed with respect to flanking /s/ in previous studies. It is also worth noting that in the case of /sb/ and the slow-rate group, there are cases of a vocalic element that acts as a transition towards the consonant, while in other cases, realizations are very close, with the presence of a clear burst. In comparison with realizations in the fast group, these realizations show the strong effect of speaking rate. Figure 4.5 show instances of the difference between slow and fast realizations for VSCV. These examples show a clear difference in constriction degree; while the fast realization of /b/ shows a formant structure that extends to high frequencies and transitions, the slow counterpart exhibits complete occlusion with a release burst.

Figure 4.5

Spectrographic images of slow (left) and fast (right) "tasbapa"



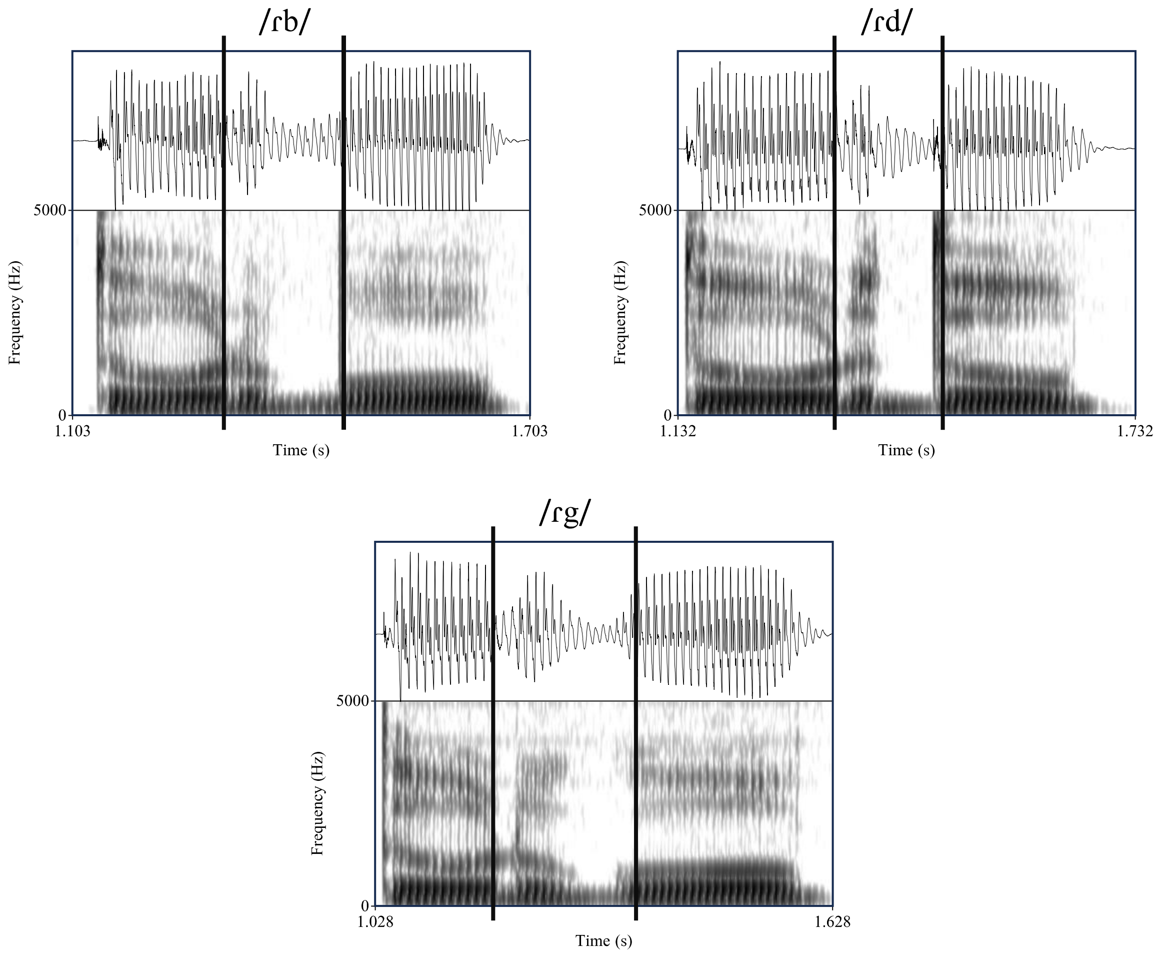
Contextual factors also include the effect of flanking vowels, so the results obtained in the rate*vowel interaction, together with the acoustic features provided by spectrographic images, are also evaluated. The effect of rate is again clearly significant in this interaction, with durations that are significantly longer in the slow-rate group. In both vowel groups in the present study (/a/ and /u/), realizations of plosive consonants appear as significantly longer in the slow-rate group than in the fast-rate group. The same is true of intensity ratio values, showing that slow realizations are potentially more constricted in the slow-rate group for both vowels. Again, this contributes to reinforcing the strong effect of rate as results are grouped by factors.

Similarly, for this interaction, in the case of the effect of vowel, results for the two variables (duration and intensity ratio) show that /b/, /d/ and /g/ are more lenited when flanked by /a/ than /u/, as it was shown for main effects. Now, it can be seen that this significance occurs in both groups, i.e., fast and slow rates. Both duration and intensity ratio show values that can be interpreted as corresponding to more consonant lenition for /a/. This result does not match other studies (Ortega-Llebaria, 2004). In fact, the case of frication noise seems to be more apparent for /u/ in the slow-rate group, which exhibits longer duration than /a/. Thus, it could be assumed that the appearance of noise can be caused by longer durations.

The results provided by two-way interactions also showed how the effect of PoA is determined by speaking rate. Consonant durations are significantly longer for the three points of articulation in the slow-rate group. Together with the significant differences in intensity ratio, it can be assumed that different rates result in different constriction degrees for /b/, /d/ and /g/. As shown in Figure 4.6, /b/, /d/ and /g/ can surface as close realizations in the slow-rate group, and in spite of some variability favoured by contextual factors (as shown above), this is most often the resulting realization. Thus, while previous studies have emphasized differences between /b/, /d/ and /g/ (Colantoni & Marinescu, 2010; Hualde et al. 2010; Recasens, 2015), the present study shows that speaking rate has an effect in the three points of articulation, triggering closer realizations in all cases.

Figure 4.6

Spectrographic images of slow /b/, /d/ and /g/ in "turbupu" (top left) "turdupu" (top right) and "turgupu" (bottom)



Lastly, the effect of rate shown on point of articulation is also supported by the results observed for the effect of PoA in the rate*PoA interaction, although this effect appears to be weaker. Previous findings have shown differences between voiced plosive realizations with respect to different points of articulation. For example, Recasens (2015) reports that /g/ becomes more lenited than /b/ and /d/ in Catalan. This is not the case in the present study for Castilian Spanish; in fact, consonant durations for /d/ and /g/ are not significantly different in either rate group, although intensity ratio results show that /d/ could be more lenited. In the slow-rate group more specifically, differences in intensity ratio are only significant between /d/ and /g/, which seems to be consistent with the results for the effect of rate, since slow rates would trigger closer realizations generally. In addition, results show that /b/ is significantly longer than /d/

and /g/ in both rate-groups, which is aligned with Recasens (2015) for Catalan, where /b/ also appears to exhibit longer durations, though not necessarily more constriction across context. In fact, intensity ratio values do not appear significantly different in /b/ vs /g/ comparisons and especially in the slow-rate group, where differences involving /b/ are not significant. Again, this reinforces the effect of time in favouring more constricted realizations in the three points of articulation, blurring differences in the comparisons.

4.1.3 Three-way interaction and lenition phenomena: duration and intensity ratio

In three-way interactions, results showed the effect of factors more precisely across levels. For an evaluation of these results, interest lies in how the effect of speaking rate interacts with different factor levels in the significance observed in the statistical tests for the three-way interactions analysed: rate*context*PoA, rate*context*vowel and rate*PoA*vowel. As shown in the quantitative results, rate remarkably keeps the observed significance in broader comparisons for all three-way interactions, except in the case of a few comparisons, most of them involving VNCV. Generally, it is also remarkable that, even though duration and intensity ratio may show some different significance results in some comparisons, intensity ratio significance is always paired with duration significance in fast-vs-slow comparisons. In the rate*context*PoA interaction, rate yields longer durations in all contexts across the three points of articulations, except for /d/ and /g/ in VNCV, while intensity ratio differences are not significant in the case of VLCV for /d/ and /b/ and VNCV for /g/. As shown previously, rate appears to yield significant differences in nasal+voiced plosive (VNCV) for both duration and intensity ratio, but three-way interactions, comparing levels more specifically, show that differences between fast and slow rates for this context are a bit less relevant. This is probably an indication that differences in coarticulation effects with nasals in homorganic sequences are not so relevant, especially in the case of /g/. The same applies to VLCV in that homorganic sequences, and the case of /d/ preceded by /l/, show similar constriction degrees in both rate groups, even though effects of rate are generally solid.

The remaining three-way interactions evaluated show a solid effect of rate across the specific factor levels. In the rate*context*vowel interaction the contrast between fast and slow is relevant across all contexts and for both vowels, although significance is less robust. Consonant durations are not significantly different for VNCV in the case of /a/, while intensity ratio differences are not significant for VNCV and VLCV in the case of /a/ (*P=.001* in both cases). The rate*PoA*vowel interaction, in turn, shows that the effect of rate is significant for /b/, /d/ and /g/ for duration and intensity ratio in the two vowel groups. The results shown in these interactions for the effect of rate are especially relevant in the present study since they emphasize its robust effect more precisely across levels. Thus, realizations in the slow-rate group are generally assumed to be more constricted across contexts and for /b/, /d/ and /g/; across contexts for each of the vowels (/a/ and /u/); and across /b/, /d/ and /g/ and for each of the vowels (/a/ and /u/).

While the effect of rate is clearly solid in the three-way interactions, it is also interesting to observe the effects of the rest of factors more specifically across levels. The effect of context in this study also yields interesting results that can be discussed in the light of previous findings (Martínez-Celdran, 2013; Recasens, 2015, for Catalan; Simonet et al., 2012 for /d/). Differences between contexts appear as significant for the two dependent variables both across the two rates and across the three points of articulation in the rate*context*PoA interaction[8]. More precisely, pairwise comparisons (see Appendix E) show that differences in intensity ratio between contexts are kept quite steady for the three points of articulation and in both rates, especially in the comparisons involving VSCV, and less remarkably in comparisons involving VCV. However, duration differences exhibit more variability in the significance observed for all contexts, losing significance across /b/, /d/ and /g/ and the two different rates. Without delving into further discussion, intensity ratio results would reinforce the similarities between VCV, VLCV and VRCV in contrast to VSCV, which appears as significantly more constricted for the three points of articulation and both speaking rates.

Similarly, in the rate*context*vowel interaction (see Appendix E), pairwise comparisons for context again reveal that differences in consonant duration exhibit variability across rates and the two vowels (/a/ and /u/). Differences in intensity ratio are less significant in comparisons involving VCV, VLCV, VRCV, and exhibit more

[8] As explained in Chapter 3, details of pairwise comparisons for the effect of context, PoA and vowel in three-way interactions are not discussed in detail and statistical results can be found in Appendixes D and E. However, according to the emphasis placed on contextual factors in previous studies, an evaluation of these results is also presented in this section.

significance in the comparisons with VSCV for both vowels. These results confirm previous findings that VSCV drives more constriction of adjacent voiced plosives, as observed in Hualde, Shosted & Scarpace (2011) and Recasens (2015) for Catalan, while VRCV and VCV favour most lenited realizations. Pairwise comparisons also show that the effect of context exhibits some variability across rates and vowels especially in those corresponding to consonant duration. Further details on these specific context comparisons are not considered central to the present study.

While the effect of context seems to be remarkable across PoA and vowel, the effect of PoA is much weaker in the rate*context*PoA interaction (as observed for broader factor interactions), appearing mainly as non-significant for intensity ratio in all contexts and both rates. This result suggests that differences in lenition across /b/, /d/ and /g/ are not so relevant as a function of context. It is also remarkable that in the case of VCV, the effect of PoA appears to be significant only in the fast-rate group. This seems to agree with previous findings for differences between points of articulation (Recasens, 2015), where /b/, /d/ and /g/ exhibit different lenition patterns according to given conditions in Catalan. His findings include that /g/ is more prone to lenition than /b/ and /d/. PoA does not appear to have a solid effect in the present study. Pairwise comparisons show only three cases of significant differences (VCV and VLCV) for intensity ratio where /g/ is involved, and more significance comparisons for duration results without a clear pattern. This result is different from rate*PoA*vowel interaction, where /b/, /d/ and /g/ appear to behave differently across fast and slow rates and across /a/ and /u/. Detail of these comparisons has been left out of further observation but statistical results are provided in Appendixes D and.

Finally, three-way interactions also showed interesting details for the effect of vowel. While the effect of vowel appeared as significant in two-way interactions, when more specific comparisons are observed, differences as a function of vowel show less significance. In the rate*context*vowel interaction, consonant duration differences are all significant across vowels for all contexts, except for VNCV, while intensity ratio values do not appear as significantly different across /a/ and /u/ for some contexts. This is the case of VNCV in both rate group, together with VRCV and VSCV, which do not show significant differences in the fast-rate group. It can be interpreted that different vowels may trigger similar constriction degrees but context favours some differences. This result would agree with previous findings (Cole et al., 1999; Ortega-Llebaria, 2004;) in that different vowels may trigger differences in the consonant constriction degrees of /b/, /d/ and /g/ in intervocalic position. It is also observed that rate favours variability, especially in intensity ratio values, since differences for VRCV and VSCV become significant for the slow rate as a function of vowel. In the rate*PoA*vowel interaction, the effect of vowel slightly decreases across PoA, and the effect of vowel is no so relevant in the case of /d/ in both rate-groups for intensity ratio. Consonant durations for /b/, /d/ and /g/ appear as significantly different across vowels in all cases, except for /d/ in the slow-rate group, showing that specific effects of vowel across factors could deserve further examination. The details of pairwise comparisons are included in Appendixes D and E.

In order to conclude the present evaluation of results, it is worth noting that the differences in consonant duration and intensity ratio observed in the outcome of the statistical tests are also apparent in the features for different constriction degrees displayed in spectrographic images. These differences are solid in the contrast between fast and slow rates generally, while they appear as more variable for the effect of the rest of factors. This variability is clearly associated with flanking segments, where some patterns for contexts can be observed. The effect of PoA also appears as significant, with observed differences between /b/, /d/ and /g/, but it also becomes more variable and lacks clear patterns in specific comparisons in three-way interactions. The same is true of the effect of vowels in the realizations of b/, /d/ and /g/, with less significance displayed in the differences in consonant constriction degrees in the interaction of /a/ and /u/ with specific factor levels in three-way interactions.

4.2 Constriction degree patterns and the temporal dimension

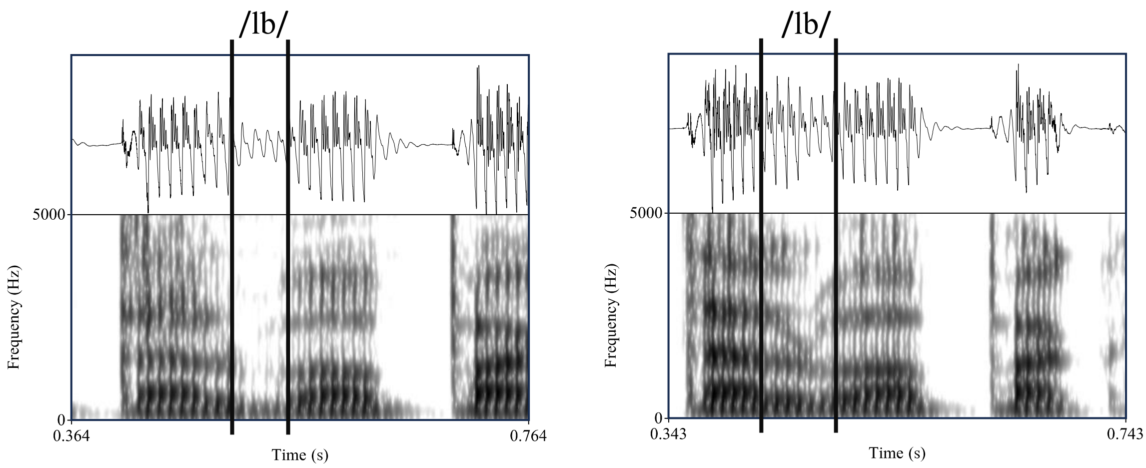
Throughout the previous discussion, different constriction degrees and different lenition patterns have been observed in relation to the effect of the factors analysed in this study. Although it is assumed that stop lenition processes encompass a range of potential constriction degrees that surface according to specific conditions, it is possible to identify some general patterns and trends that are associated with the effect of the factors analysed. These observations are not intended to categorize stricture types or to provide statistical data of the occurrence frequency of different realization types. Instead, the purpose is to provide further evidence that supports the hypotheses stated in this study with respect to the role of time in fast and slow utterances.

In spite of some variability that may occur in both rate groups driven by the effect of factors, it can be stated that some specific features are recurrent in each of them. The contexts that have traditionally been claimed to trigger lenition (VCV, VLCV, VRCV and VSCV), actually favour different realizations that are paired with different acoustic features. These can be considered trends in this study, as they are associated with fast and/or slow utterances. Realizations in the fast-rate group generally show intense sonority in the form of a sonority bar, clear glottal pulses, and a formant structure. In contrast, the slow-rate group is frequently associated with more stop-like features, such as a sonority bar, weak sonority pulses, and a release burst is some cases.

Different constriction degrees have shown some recurrent features that can also be identified as trends in the sample in this study. Less constricted realizations may appear almost as intense as a vowel, where clear boundaries are very difficult to identify. Alternatively, a weaker, less intense version is also quite common, with weaker glottal pulses. Both of them show a steady formant structure in the transition from and to flanking segments. Regarding the corresponding acoustic cues selected in this study for constriction degree, durations are shorter, and intensity ratio values are closer to 1 than for the rest of realizations (see Figure 4.7 for spectrographic images of these trends). In the present study, if we look into the factors that trigger these realizations, they appear associated to fast speaking rates, where more open realizations appear in the VCV context that could be identified as approximants. However, approximant-like realizations also surface quite frequently in VLCV and VRCV, which illustrates previously reported occurrence after sonorant segments.

Figure 4.7

Spectrographic images of two approximant realizations of /b/ in talbapa



In contrast, more constricted realizations surface as more occluded to different degrees. In some utterances, they exhibit some glottal pulses over the sonority bar that fade away and a clear burst in not apparent, indicating that a complete occlusion is probably very brief or it does not occur. It has been observed that this is a trend in realizations at the fast rate in VSCV and VRCV contexts, but occurrence increases in the slow rate for all contexts, and quite commonly for VCV (see Figure 4.2 for a spectrographic image). As shown in Figure 4.5 above, still more occluded realizations may also surface, exhibiting a clear release burst. These have been identified in slow utterances in most cases, and apparently more frequently when preceded by /s/ (VSCV). It has also been observed that after /s/ and in the slow-rate group, a devoiced realization also surfaces in the case of /d/, going one step further in closer constriction degrees. Finally, it should be noted that another remarkable feature has been identified in a number of utterances, namely, the case of frication noise. As mentioned above, this fricative realization surfaces more clearly in the slow-rate group, where longer durations may allow for the achievement of closer constriction degree configurations that favour sustained intra-oral pressure build-up.

4.3 Evaluation of the stated hypotheses

As stated in Chapter 1 in this dissertation, the hypothesized principle underlying Spanish stop lenition involves a reduction in gestural magnitude that triggers undershot realizations of the target voiced plosive consonants. This principle can account for the variability observed in previous descriptions of the phenomenon, where contextual factors are posited to trigger different constriction degrees. Although the current study looks into the effect of contextual factors, it aims to go a step further in the analysis of the variability observed. It has been stated that this undershoot assumed in Spanish lenition processes is driven by the time involved in the production of the sequences that favour consonant weakening, yielding different outcomes.

Thus, the first hypothesized assumption was intended to show how a categorization of Spanish stop lenition outcomes and processes that is based on the effect of flanking segments only accounts for the phenomenon partially. In this study, the data collected and analysed for two different speaking rates have provided evidence that time plays a crucial role, since the features of resulting realizations for the analysed sequences are also determined by the time dimension. Although it has been shown that flanking segments trigger different constriction degrees across the two speaking rates, a strict categorization of stop lenition based on contextual factors clearly loses strength with the effect of the time dimension. This dissertation has shown that when more time is allowed to attempt those sequences, undershoot is diminished, resulting in longer, more occluded realizations, so effects of contextual factors are modified as a result of the action of time. This reinforces the idea that we are facing a generic, phonetic-based phenomenon as well as a specific language-based process.

The second hypothesized assumption focused on the determining role of time (and consonant duration) in stop lenition in Spanish and its interaction with contextual factors. Throughout the presentation and the evaluation of results, evidence has been provided showing how time shapes the resulting realizations of stop lenition processes. The slow rate promotes more constricted realizations, illustrated by acoustic features, even when the outcome does not involve a complete closure. The comparisons between fast and slow realizations have yielded significant differences in virtually all the cases, which is interpreted as clearly validating the stated hypotheses. The spectrographic images also show features corresponding to different constriction degrees, where slow realizations are more occluded, thus providing a picture of the effects of time as hypothesized.

Regarding the effect of contextual factors, evidence has shown some facts that agree with previous findings. It has been shown that intervocalic positions favour vowel-like realizations in the fast-rate group. Among the consonant sequences, a preceding /s/ favours more occluded realizations, while preceding sonorants trigger more lenited ones. However, the slow-rate group offers a different picture, where differences in constriction degrees, although showing significance, fall within a range of more constricted realizations. This shows that, in the comparison between fast and slow, constriction degree and duration go along in the phenomenon, since longer consonant durations differences are shown to pair with other acoustic cues for more constricted realizations.

As these effects are analysed, the interaction of factors has also provided evidence that the variability observed as determined by contextual factors is modified by the effect of time. It has been observed that there is still variability associated with different flanking segments but, in the comparisons between fast and slow realizations across other factors levels, it has been observed that other strategies and processes are activated to aim for the target consonant. For example, it has been found that more time allows the speaker to achieve complete occlusions, producing a stop-like realization, or resulting in a continuous air flow that allows the necessary pressure to create air turbulence, with the corresponding presence of friction noise. Still another possibility is the introduction of a vocalic element, not only in VRCV, but also in VSCV and VLCV in a few cases, with the corresponding decreased constriction. As a consequence of the observed facts, it can be concluded that the variability associated with contextual factors is modified by the effect of the temporal dimension. In the slow rate, spectrographic images show that significant differences between contexts do not encompass approximant vs stop realizations, since they all exhibit features of more occluded productions. However, those differences indicate that time and context interact, yielding decreased gestural overlap effects and promoting different strategies to attempt the given consonant clusters or intervocalic sequences.

4.4 The phonology of voiced stop lenition in Castilian Spanish: Articulatory Phonology

As explained in Chapter 1, the current work relies on Articulatory Phonology as a theoretical framework that can account for a complex, gradient phenomenon such as the processes involved in Spanish stop lenition. Considering a task dynamics perspective, AP views coarticulation phenomena and lenition as governed by dynamics laws, where the action of events has an effect on task outcome. The inclusion of the spatio-temporal dimension involved in gestures provides a framework that can account for different phonological processes, such as epenthesis, assimilation, and deletion, which can be explained in terms of the coordination of articulatory gestures in time (Romero, 1995; Hualde, 2005).

The main premise assumed for the process involved in Spanish stop lenition is an articulatory undershoot of a given target, as a result of gestural reduction. As suggested in Romero (1995) this reduction is extended in time to the complete CV or CC sequence allowing gestural overlap, undershoot and continuous air flow. He also suggests that in nasal+C sequences (VNCV in the current study), a longer gesture drives the action of different articulators, and reduction does not occur, such as the action of the lips in /mb/. Thus, in the light of the results presented in this dissertation and from the perspective of Articulatory Phonology, voiced stop lenition can be explained as a result of gesture mechanisms whereby constriction degree and constriction location dimensions are determined by time along a continuum.

The question that remains to be answered is: does this combination of events arise from an abstract underlying representation of phonemes in a given language? Does it arise from the phonetic task at hand driven by specific conditions? Along the lines of Articulatory Phonology premises, it is assumed that articulatory gestures are simultaneously the units of phonetic and phonological organization of a language (Browman & Goldstein, 1992). Browman & Goldstein also explain that variation along the same phonetic dimension is in fact a unified phenomenon, and should not be explained as allophone vs underlying phonemic representation. In the present work, it is assumed that articulatory gestures can provide the phonetic/phonological unit adopting the required configuration to produce a given sound or sound sequence. It is also believed that, in spite of the variability observed in coarticulatory phenomena, invariance may finally stand out, as the present work has also shown in some of the trends observed. This interpretation is aligned with Blumstein & Stevens (1979), as they identify a set of invariant acoustic properties for English voiced and voiceless plosives that are perceived and produced by the speakers of a language. Further, considering that speakers are not aware of differences between lenited and non-lenited realizations (Recasens, 2015), lenition may be understood as involving language-driven structures that allow speakers to recognize and produce sequences to accomplish the task at hand.

4.5 Concluding remarks

The present work has delved into the non-categorical nature of Spanish stop lenition by providing evidence that the multi-dimensionality of the phenomenon goes beyond the effects of contextual conditions and their categorization. Although the current study does not provide a full characterization of the effect of contextual factors from the perspective of the articulatory mechanisms involved, it has shown that the nature of flanking segments probably accounts for a lot of the variability observed in the lenition of voiced plosives in Castilian Spanish. However, this work has also stated that these effects are not categorical either, in that generalizations for different contexts cannot be assumed completely. The effect of rate in this study has shown how time is responsible for other conditions that produce a different outcome, which indicates that both factors. i.e., rate, context (including vowel) must be considered in any description of the phenomenon.

Recent studies have also referred to the effect of other factors in Spanish stop lenition which may contribute to emphasizing the phonetic nature of the phenomenon.

Although no specific experimental data is provided, some studies have referred to some effect of speaking style in the production of weakened voiced stop realizations. Hualde & Zhang (2023) state that an effect of speaking style is observed in the realization of intervocalic /p, t, k/ in Central Catalan. According to their observations, it is also suggested that different styles favour different lenition outcomes in Catalan, while duration does not appear to be responsible for voicing and approximantization.

In the light of the experimental data collected and analysed in this current work, a trend has been observed on the part of speakers to use different styles in the production of the tokens included in the inventory. Although it is not investigated specifically, an emphatic vs. a comfortable style have been observed in general terms as participants attempted to read the target words in the inventory. It is believed that this emphatic style is not associated with effort as understood in Kirchner (2004). It has been observed that laboratory conditions and reading target words (though prompted) may promote higher awareness of correctness as perceived by speakers. It is believed that this may result in more careful pronunciation of the target tokens, since a rough observation of spectrographic images shows a trend to lenite other voiced and voiceless plosive consonants (other than the target token) in the carrier sentence. This speaker-dependence is also mentioned in Recasens (2018) for coarticulation involving lingual gestures, where he suggests that different speakers use different coarticulation mechanisms and information to produce a given sequence or to recognize it.

According to the observations made in this final section, it is suggested that further research could benefit from including more detailed observation of how the effect of contextual factors is modified by the effect of time in the light of articulatory data. It is assumed that some of the articulatory data used in previous studies (electromagnetic articulography) involve complex equipment conditions and experimental procedures. However other methods are being investigated to provide articulatory data, such as a combination of ultrasound and optoelectronic data that would allow for synchronous observation of labial and lingual data. This could also include the study of other factors, such as speaking style, to describe voiced stop lenition as an effect of contextual factors and style, driven by temporally-conditioned articulatory configurations and regular patterns for a given language or variety.

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Appendix A

Questionnaire administered to subjects

Por favor, completa los datos o responde las preguntas según corresponda:

Nombre: ______________________________

Apellidos: ______________________________

1. Fecha de nacimiento:

   ____

2. Lugar de nacimiento:

   ____

3. Lengua maternal (hablada en casa):

   ____

4. Lugar de procedencia de tus padres:

   ____

5. ¿Dónde resides en la actualidad? ¿Cuánto tiempo hace que resides en ese lugar?

   ____

6. ¿Has vivido más de 6 meses en algún otro lugar de España? Si la respuesta es “SÍ”, por favor, especifica dónde.

   ____

7. ¿Has tenido alguna vez problemas de habla o de lenguaje? Si la respuesta es “SÍ”, por favor, especifica qué problema.

   ____

8. ¿Estuviste en contacto con hablantes de otras lenguas durante tu infancia? Si la respuesta es “SÍ”, por favor, especifica la/s lengua/s.

   ____

9. ¿Estás en contacto con hablantes de otras lenguas? Si la respuesta es “SÍ”, especifica la/s lengua/s e indica con qué frecuencia.

   ____

   ☐ cada día

☐ frecuentemente

☐ una vez a la semana

☐ una vez al mes

10. ¿Hablas otras lenguas? Si la respuesta es "SÍ", por favor, especifica la/s lengua/s.

____

11. ¿Podrías identificar tu acento español con el de alguna zona geográfica de España? Si tu respuesta es "SÍ", por favor, indica cuál.

____

12. ¿Cuál de estas palabras inventadas te suena más española? Escoge una respuesta.

☐ tabapa ☐ tubupu ☐ Las dos por igual

13. ¿Cuál de estas palabras inventadas te parece más difícil de pronunciar? Escoge una respuesta.

☐ tagapa ☐ tugupu ☐ Las dos por igual

14. ¿Te parece más fácil de pronunciar la palabra española "*abjurar*" que las palabras inventadas "*tubupu*" y "*tugupu*"

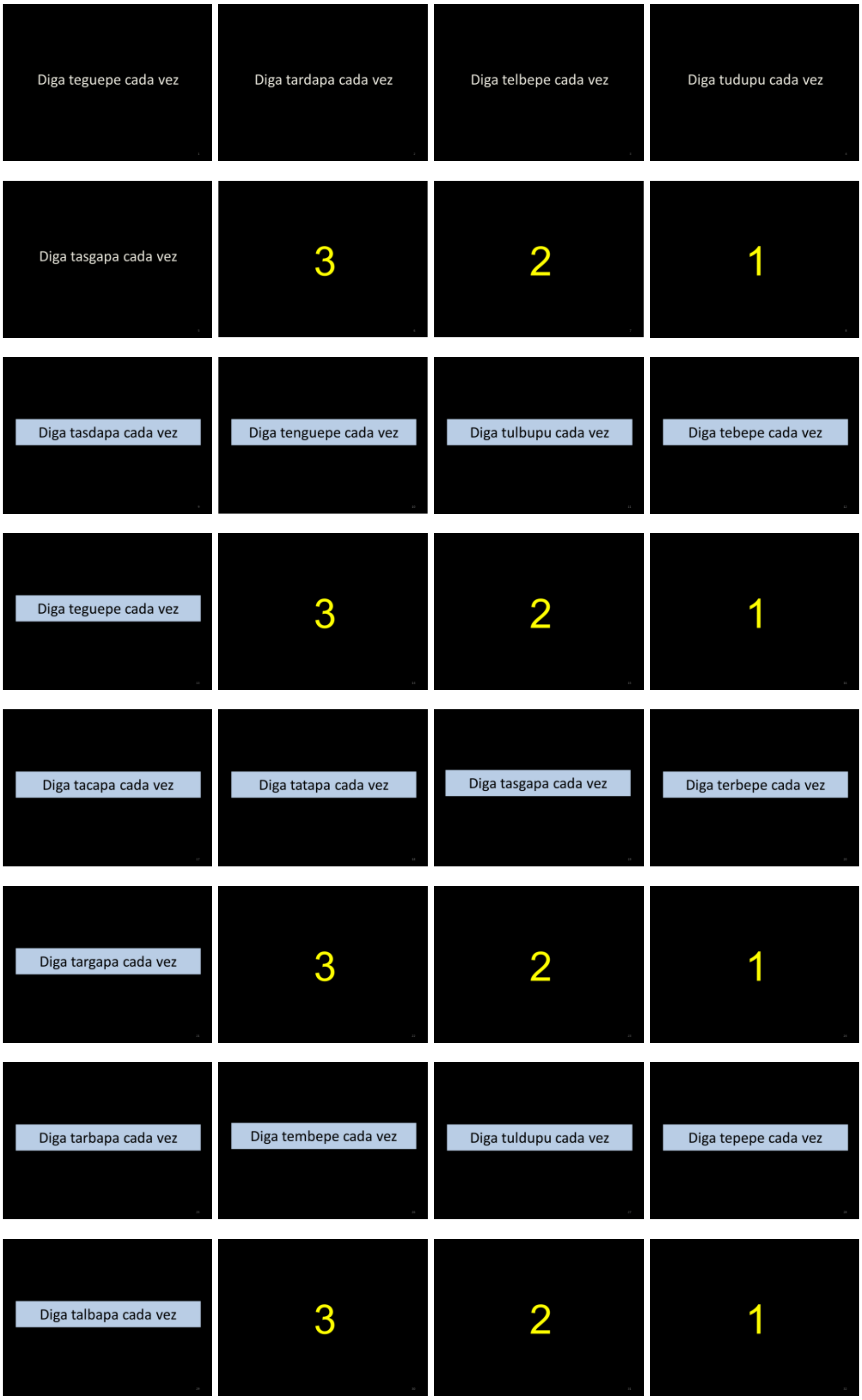
____

☐ SÍ ☐ NO

Appendix B

Stimuli presentation

Example of stimuli presentation in randomized order as PowerPoint prompts



Appendix C

Praat scripts

Praat scripts for derivative curve extraction and segmentation

```
###############
Erase all
#PART 1
#TIME
#DERIVADA + TEXTGRID
ini = 0.0
fin = 0.0
To Intensity... 100 0.0
Copy... derivada
Formula... (self[col+1]-self[col])/dx
Down to IntensityTier
Rename... derivada
select Sound ___________
plus IntensityTier derivada
Edit
select IntensityTier derivada
Down to PointProcess
To TextGrid... label label
select Sound ___________
plus TextGrid derivada
Edit
select TextGrid derivada
Down to Table... no 10 yes no
```

Praat script for duration values

```
#TIMES
select TextGrid derivada
l1 = Get time of point... 1 1
clearinfo
```

```
printline l1
print 'l1'
select TextGrid derivada
l2 = Get time of point... 1 2
printline
printline l2
print 'l2'
select TextGrid derivada
l3 = Get time of point... 1 3
printline
printline l3
print 'l3'
clearinfo
select Intensity derivada
time1 = Get time of minimum... l1 l2 parabolic
print tmincons 'time1'
clearinfo
select Intensity derivada
time2 = Get time of maximum... l1 l2 parabolic
print tmaxcons 'time2'
clearinfo
select Intensity derivada
time3 = Get time of minimum... l2 l3 parabolic
print tminvo 'time3'
clearinfo
print tmincons'tab$'tmaxcons'tab$'tminvo
printline
print 'time1''tab$''time2''tab$''time3'
```

Praat script for intensity values

```
select Sound __________
plus IntensityTier derivada
Edit
select Sound __________
```

```
plus TextGrid derivada
Edit
start = time1
end = time2
editor TextGrid derivada
    Select... start end
endeditor
#PART 2
#INTENSITY
clearinfo
select Intensity ___________
intensity1 = Get minimum... time1 time2 parabolic
print intensity cons 'intensity1'
clearinfo
select Intensity ___________
intensity2 = Get maximum... time2 time3 parabolic
print intensity vo 'intensity2'
clearinfo
print intensity cons'tab$'intensity vo
printline
print 'intensity1"tab$"intensity2'
```

Appendix D

Pairwise comparison results for three-way interactions for context, PoA and vowel for duration

Table D.1

Pairwise comparison results for the effect of context across rate and vowel for duration

DURATION /a/																				
Vowel*Rate	FAST								SLOW											
Context			VCV	VLCV	VNCV	VOV	VRCV	VSCV			VCV	VLCV	VNCV	VOV	VRCV	VSCV				
	M	*SD*	*mean comparisons (p)*						*M*	*SD*	*mean comparisons (p)*									
VCV	28.585	6.657		1	.012	<.001	.016	.001	61.452	14.954		<.001	<.001	<.001	1	1				
VLCV	32.712	10.121			<.001	<.001	1	.821	51.836	13.116			<.001	<.001	<.001	<.001				
VNCV	23.287	5.946				<.001	<.001	<.001	27.888	10.223				<.001	<.001	<.001				
VOV	57.341	15.033					<.001	<.001	108.494	23.004					<.001	<.001				
VRCV	33.763	10.431						1	60.914	14.854						1				
VSCV	34.916	10.341							59.522	17.324										

DURATION /a/															
Vowel*Rate	FAST								SLOW						
Context			VCV	VLCV	VNCV	VOV	VRCV	VSCV			VCV	VLCV	VNCV	VOV	VRCV	VSCV
	M	*SD*	*mean comparisons (p)*						*M*	*SD*	*mean comparisons (p)*					
VCV	28.585	6.657		1	.012	<.001	.016	.001	61.452	14.954		<.001	<.001	<.001	1	1
VLCV	32.712	10.121			<.001	<.001	1	.821	51.836	13.116			<.001	<.001	<.001	<.001
VNCV	23.287	5.946				<.001	<.001	<.001	27.888	10.223				<.001	<.001	<.001
VOV	57.341	15.033					<.001	<.001	108.494	23.004					<.001	<.001
VRCV	33.763	10.431						1	60.914	14.854						1
VSCV	34.916	10.341							59.522	17.324						

Table D.2

Pairwise comparison results for the effect of context across rate and PoA for duration

DURATION /b/															
PoA*Rate	FAST								SLOW						
Context			VCV	VLCV	VNCV	VOV	VRCV	VSCV			VCV	VLCV	VNCV	VOV	VRCV	VSCV
	M	*SD*	*mean comparisons (p)*						*M*	*SD*	*mean comparisons (p)*					
VCV	37.024	12.698		.041	<.001	<.001	<.001	.001	67.513	19.702		1	<.001	<.001	1	1
VLCV	44.403	11.813			<.001	<.001	1	1	68.133	11.625			<.001	<.001	1	1
VNCV	24.883	9.179				<.001	<.001	<.001	35.610	14.373				<.001	<.001	<.001
VOV	68.956	16.038					<.001	<.001	116.312	19.670					<.001	<.001
VRCV	45.253	12.636						1	66.969	15.578						1
VSCV	45.003	11.280							65.497	19.154						

DURATION /d/

PoA*Rate Context	FAST *M*	FAST *SD*	VCV	VLCV	VNCV	VOV	VRCV	VSCV	SLOW *M*	SLOW *SD*	VCV	VLCV	VNCV	VOV	VRCV	VSCV
			mean comparisons (p)								*mean comparisons (p)*					
VCV	32.011	10.485		1	<.001	<.001	1	1	65.416	14.465		<.001	<.001	<.001	.057	1
VLCV	32.692	14.329			<.001	<.001	1	1	46.612	18.455			<.001	<.001	<.001	<.001
VNCV	22.303	4.870				<.001	<.001	<.001	26.295	7.866				<.001	<.001	<.001
VOV	57.568	11.128					<.001	<.001	117.176	17.276					<.001	<.001
VRCV	33.749	9.350						1	71.029	17.308						.242
VSCV	30.785	10.247							66.365	17.922						

DURATION /g/

PoA*Rate Context	FAST *M*	FAST *SD*	VCV	VLCV	VNCV	VOV	VRCV	VSCV	SLOW *M*	SLOW *SD*	VCV	VLCV	VNCV	VOV	VRCV	VSCV
			mean comparisons (p)								*mean comparisons (p)*					
VCV	37.136	10.385		1	<.001	<.001	1	1	71.177	16.964		.001	<.001	<.001	.001	.001
VLCV	37.516	11.575			<.001	<.001	1	1	63.588	16.031			<.001	<.001	1	1
VNCV	20.027	4.072				<.001	<.001	<.001	24.260	7.446				<.001	<.001	<.001
VOV	55.248	11.030					<.001	<.001	106.132	26.286					<.001	<.001
VRCV	34.883	10.594						.720	66.969	15.578						1
VSCV	38.715	10.818							63.428	15.880						

Table D.3

Pairwise comparison results for the effect of PoA across rate and context for duration

DURATION

Context*Rate	PoA	VCV *M*	VCV *SD*	FAST /b/	FAST /d/	FAST /g/	SLOW /b/	SLOW /d/	SLOW /g/	VLCV *M*	VLCV *SD*	FAST /b/	FAST /d/	FAST /g/	SLOW /b/	SLOW /d/	SLOW /g/
				mean comparison (p)								*mean comparison (p)*					
FAST	/b/	37.024	12.698		.029	1				44.403	11.813		<.001	.006			
	/d/	32.011	10.485			.250				32.692	14.329			.093			
	/g/	37.136	10.385							37.516	11.575						
SLOW	/b/	67.513	19.702					.837	.176	68.133	11.625					<.001	.127
	/d/	65.416	14.465						.009	46.612	18.455						<.001
	/g/	71.177	16.964							63.588	16.031						

DURATION

Context*Rate	PoA	VNCV *M*	VNCV *SD*	FAST /b/	FAST /d/	FAST /g/	SLOW /b/	SLOW /d/	SLOW /g/	VOV *M*	VOV *SD*	FAST /b/	FAST /d/	FAST /g/	SLOW /b/	SLOW /d/	SLOW /g/
				mean comparison (p)								*mean comparison (p)*					
FAST	/b/	24.883	9.179		.549	.037				68.956	16.038		<.001	<.001			
	/d/	22.303	4.870			.720				57.568	11.128			.693			
	/g/	20.027	4.072							55.248	11.030						
SLOW	/b/	35.610	14.373					<.001	<.001	116.312	19.670					1	<.001
	/d/	26.295	7.866						.881	117.176	17.276						<.001
	/g/	24.260	7.446							106.132	26.286						

DURATION																	
		VRCV								VSCV							
Context*Rate				FAST			SLOW					FAST			SLOW		
PoA				/b/	/d/	/g/	/b/	/d/	/g/			/b/	/d/	/g/	/b/	/d/	/g/
		M	*SD*	*mean comparison (p)*						*M*	*SD*	*mean comparison (p)*					
FAST	/b/	45.253	12.636		<.001	<.001				45.003	11.280		<.001	.004			
	/d/	33.749	9.350			1				30.785	10.247			<.001			
	/g/	34.883	10.594							38.715	10.818						
SLOW	/b/	66.969	15.578					.108	.164	65.497	19.154					1	.857
	/d/	71.029	17.308						<.001	66.365	17.922						.389
	/g/	63.245	18.177							63.428	15.880						

Table D.4

Pairwise comparison results for the effect of PoA across rate and vowel for duration

DURATION										
/a/										
Vowel*Rate			FAST					SLOW		
PoA			/b/	/d/	/g/			/b/	/d/	/g/
	M	*SD*	*mean comparisons (p)*			*M*	*SD*	*mean comparisons (p)*		
/b/	40.459	17.375		<.001	<.001	62.205	27.350		.105	.008
/d/	33.151	13.889			1	65.359	32.594			<.001
/g/	32.003	11.465				58.773	27.163			

DURATION										
/u/										
Vowel*Rate			FAST					SLOW		
PoA			/b/	/d/	/g/			/b/	/d/	/g/
	M	*SD*	*mean comparisons (p)*			*M*	*SD*	*mean comparisons (p)*		
/b/	48.035	18.458		<.001	<.001	77.969	29.778		<.001	<.001
/d/	36.739	15.945			<.001	67.246	31.736			<.001
/g/	42.483	15.213				71.986	31.382			

Table D.5

Pairwise comparison results for the effect of vowel across rate and context for duration

DURATION									
		VCV				VLCV			
Context*Rate				FAST	SLOW			FAST	SLOW
Vowel				/a/ vs /u/				/a/ vs /u/	
		M	*SD*	*mean comparisons (p)*		*M*	*SD*	*mean comparisons (p)*	
FAST	/a/	28.585	6.657	<.001		32.712	10.121	<.001	
	/u/	42.196	11.199			43.695	14.167		
SLOW	/a/	61.452	14.954		<.001	51.836	13.116		<.001
	/u/	74.618	16.971			67.053	19.239		

DURATION									
		VNCV				VOV			
Context*Rate				FAST	SLOW			FAST	SLOW
Vowel				/a/ vs /u/				/a/ vs /u/	
		M	*SD*	*mean comparisons (p)*		*M*	*SD*	*mean comparisons (p)*	
FAST	/a/	23.287	5.946	.264		57.341	15.033	<.001	
	/u/	21.521	7.328			63.840	12.603		
SLOW	/a/	27.888	10.223		.292	108.494	23.004		<.001
	/u/	29.554	12.584			117.920	19.759		

DURATION									
		VRCV				VSCV			
Context*Rate				FAST	SLOW			FAST	SLOW
Vowel				/a/ vs /u/				/a/ vs /u/	
		M	*SD*	*mean comparisons (p)*		*M*	*SD*	*mean comparisons (p)*	
FAST	/a/	33.763	10.431	<.001		34.916	10.341	<.001	
	/u/	42.161	12.174			41.420	13.109		
SLOW	/a/	60.914	14.854		<.001	59.522	17.324		<.001
	/u/	73.248	17.388			70.671	16.262		

Table D.6

Pairwise comparison results for the effect of vowel across rate and PoA for duration

DURATION						
/b/						
PoA*Rate	FAST			SLOW		
Vowel	/a/ vs /u/			/a/ vs /u/		
	M	*SD*	*mean comparisons (p)*	*M*	*SD*	*mean comparisons (p)*
/a/	40.459	17.375	<.001	62.205	27.350	<.001
/u/	48.035	18.458		77.969	29.778	

DURATION						
/d/						
PoA*Rate	FAST			SLOW		
Vowel	/a/ vs /u/			/a/ vs /u/		
	M	*SD*	*mean comparisons (p)*	*M*	*SD*	*mean comparisons (p)*
/a/	33.151	13.889	.001	65.359	32.594	.068
/u/	36.739	15.945		67.246	31.736	

DURATION						
/g/						
PoA*Rate	FAST			SLOW		
Vowel	/a/ vs /u/			/a/ vs /u/		
	M	*SD*	*mean comparisons (p)*	*M*	*SD*	*mean comparisons (p)*
/a/	32.003	11.465	<.001	58.773	27.163	<.001
/u/	42.483	15.213		71.986	31.382	

Appendix E

Pairwise comparison results for three-way interactions for context, PoA and vowel for intensity ratio

Table E.1

Pairwise comparison results for the effect of context across rate and vowel for INT-R

INT-R /a/																
Vowel*Rate	FAST								SLOW							
Context			VCV	VLCV	VNCV	VOV	VRCV	VSCV			VCV	VLCV	VNCV	VOV	VRCV	VSCV
	M	*SD*	*mean comparisons (p)*						*M*	*SD*	*mean comparisons (p)*					
VCV	.936	.053		.144	.110	<.001	<.001	<.001	.834	.087		.019	<.001	<.001	1	<.001
VLCV	.902	.060			1	<.001	.009	<.001	.863	.083			1	<.001	<.001	<.001
VNCV	.909	.032				<.001	.002	<.001	.877	.053				<.001	<.001	<.001
VOV	.657	.071					<.001	<.001	.534	.071					<.001	<.001
VRCV	.871	.067						<.001	.823	.101						<.001
VSCV	.798	.099							.735	.118						

INT-R /u/																
Vowel*Rate	FAST								SLOW							
Context			VCV	VLCV	VNCV	VOV	VRCV	VSCV			VCV	VLCV	VNCV	VOV	VRCV	VSCV
	M	*SD*	*mean comparisons (p)*						*M*	*SD*	*mean comparisons (p)*					
VCV	.888	.064		.838	.840	<.001	.027	<.001	.802	.103		.675	<.001	<.001	.066	<.001
VLCV	.862	.060			.004	<.001	1	<.001	.775	.107			<.001	<.001	1	<.001
VNCV	.907	.046				<.001	<.001	<.001	.868	.042				<.001	<.001	<.001
VOV	.619	.090					<.001	<.001	.516	.088					<.001	<.001
VRCV	.857	.062						<.001	.774	.116						<.001
VSCV	.803	.088							.700	.129						

Table E.2

Pairwise comparison results for the effect of context across rate and PoA for INT-R

INT-R /b/																
PoA *Rate	FAST								SLOW							
Context			VCV	VLCV	VNCV	VOV	VRCV	VSCV			VCV	VLCV	VNCV	VOV	VRCV	VSCV
	M	*SD*	*mean comparisons (p)*						*M*	*SD*	*mean comparisons (p)*					
VCV	0.920	0.055		.002	1	<.001	<.001	<.001	0.804	0.095		.339	<.001	<.001	1	<.001
VLCV	0.863	0.058			.034	<.001	.928	<.001	0.828	0.064			.138	<.001	.139	<.001
VNCV	0.910	0.040				<.001	<.001	<.001	0.869	0.055				<.001	<.001	<.001
VOV	0.639	0.096					<.001	<.001	0.516	0.077					<.001	<.001
VRCV	0.844	0.070						<.001	0.800	0.095						<.001
VSCV	0.787	0.095							0.721	0.124						

INT-R /d/

PoA *Rate Context	FAST *M*	FAST *SD*	FAST VCV	FAST VLCV	FAST VNCV	FAST VOV	FAST VRCV	FAST VSCV	SLOW *M*	SLOW *SD*	SLOW VCV	SLOW VLCV	SLOW VNCV	SLOW VOV	SLOW VRCV	SLOW VSCV
			mean comparisons (p)								*mean comparisons (p)*					
VCV	0.934	0.054		1	1	<.001	<.001	<.001	0.842	0.080		.066	.096	<.001	.835	<.001
VLCV	0.907	0.053			1	<.001	.035	<.001	0.874	0.065			1	<.001	<.001	<.001
VNCV	0.920	0.041				<.001	.002	<.001	0.876	0.040				<.001	<.001	<.001
VOV	0.658	0.075					<.001	<.001	0.539	0.090					<.001	<.001
VRCV	0.872	0.054						<.001	0.819	0.110						<.001
VSCV	0.800	0.089							0.700	0.130						

INT-R /g/

PoA *Rate Context	FAST *M*	FAST *SD*	FAST VCV	FAST VLCV	FAST VNCV	FAST VOV	FAST VRCV	FAST VSCV	SLOW *M*	SLOW *SD*	SLOW VCV	SLOW VLCV	SLOW VNCV	SLOW VOV	SLOW VRCV	SLOW VSCV
			mean comparisons (p)								*mean comparisons (p)*					
VCV	0.882	0.068		1	1	<.001	1	<.001	0.809	0.109		.004	<.001	<.001	.161	<.001
VLCV	0.875	0.071			1	<.001	1	<.001	0.755	0.134			<.001	<.001	1	.340
VNCV	0.895	0.034				<.001	1	<.001	0.873	0.047				<.001	<.001	<.001
VOV	0.617	0.071					<.001	<.001	0.519	0.071					<.001	<.001
VRCV	0.875	0.066						<.001	0.777	0.126						.002
VSCV	0.816	0.096							0.730	0.118						

Table E.3

Pairwise comparison results for the effect of PoA across rate and context for INT-R

INT-R

Context*Rate	PoA	VCV *M*	VCV *SD*	FAST /b/	FAST /d/	FAST /g/	SLOW /b/	SLOW /d/	SLOW /g/	VLCV *M*	VLCV *SD*	FAST /b/	FAST /d/	FAST /g/	SLOW /b/	SLOW /d/	SLOW /g/
				mean comparison (p)								*mean comparison (p)*					
FAST	/b/	0.920	0.055		.725	.006				0.863	0.058		.006	1			
	/d/	0.934	0.054			<.001				0.907	0.053			.075			
	/g/	0.882	0.068							0.875	0.071						
SLOW	/b/	0.804	0.095					.006	1	0.828	0.064					.004	<.001
	/d/	0.842	0.080						.018	0.874	0.065						<.001
	/g/	0.809	0.109							0.755	0.134						

INT-R

Context*Rate	PoA	VNCV *M*	VNCV *SD*	FAST /b/	FAST /d/	FAST /g/	SLOW /b/	SLOW /d/	SLOW /g/	VOV *M*	VOV *SD*	FAST /b/	FAST /d/	FAST /g/	SLOW /b/	SLOW /d/	SLOW /g/
				mean comparison (p)								*mean comparison (p)*					
FAST	/b/	0.910	0.040		1	.743				0.639	0.096		.355	.189			
	/d/	0.920	0.041			.138				0.658	0.075			.002			
	/g/	0.895	0.034							0.617	0.071						
SLOW	/b/	0.869	0.055					1	1	0.516	0.077					.175	1
	/d/	0.876	0.040						1	0.539	0.090						.295
	/g/	0.873	0.047							0.519	0.071						

INT-R																		
		VRCV								VSCV								
Context*Rate				FAST			SLOW					FAST			SLOW			
PoA				/b/	/d/	/g/	/b/	/d/	/g/			/b/	/d/	/g/	/b/	/d/	/g/	
		M	*SD*	*mean comparison (p)*						*M*	*SD*	*mean comparison (p)*						
FAST	/b/	0.844	0.070		.065	.038				0.787	0.095		.850	.046				
	/d/	0.872	0.054			1				0.800	0.089			.530				
	/g/	0.875	0.066							0.816	0.096							
SLOW	/b/	0.800	0.095					.363	.201	0.721	0.124					.263	1	
	/d/	0.819	0.110						.002	0.700	0.130						.043	
	/g/	0.777	0.126							0.730	0.118							

Table E.4

Pairwise comparison results for the effect of PoA across rate and vowel for INT-R

INT-R										
/a/										
Vowel*Rate	FAST					SLOW				
PoA			/b/	/d/	/g/			/b/	/d/	/g/
	M	*SD*	*mean comparisons (p)*			*M*	*SD*	*mean comparisons (p)*		
/b/	0.817	0.113		<.001	<.001	0.760	0.144		<.001	.399
/d/	0.862	0.118			.379	0.788	0.153			.045
/g/	0.851	0.116				0.774	0.147			

INT-R										
/u/										
Vowel*Rate	FAST					SLOW				
PoA			/b/	/d/	/g/			/b/	/d/	/g/
	M	*SD*	*mean comparisons (p)*			*M*	*SD*	*mean comparisons (p)*		
/b/	0.834	0.127		1	<.001	0.746	0.151		.677	<.001
/d/	0.831	0.112			<.001	0.754	0.150			<.001
/g/	0.798	0.120				0.713	0.153			

Table E.5

Pairwise comparison results for the effect of vowel across rate and context for INT-R

INT-R									
		VCV				VLCV			
Context*Rate				FAST	SLOW			FAST	SLOW
Vowel				/a/ vs /u/				/a/ vs /u/	
		M	*SD*	*mean comparisons (p)*		*M*	*SD*	*mean comparisons (p)*	
FAST	/a/	.936	.053	<.001		.902	.060	<.001	
	/u/	.888	.064			.862	.060		
SLOW	/a/	.834	.087		.001	.863	.083		<.001
	/u/	.802	.103			.775	.107		

INT-R									
		VNCV				VOV			
Context*Rate				FAST	SLOW			FAST	SLOW
Vowel				/a/ vs /u/				/a/ vs /u/	
		M	*SD*	*mean comparisons (p)*		*M*	*SD*	*mean comparisons (p)*	
FAST	/a/	.909	.032	.841		.657	.071	<.001	
	/u/	.907	.046			.619	.090		
SLOW	/a/	.877	.053		.401	.534	.071		.061
	/u/	.868	.042			.516	.088		

INT-R									
		VRCV				VSCV			
Context*Rate				FAST	SLOW			FAST	SLOW
Vowel				/a/ vs /u/				/a/ vs /u/	
		M	*SD*	*mean comparisons (p)*		*M*	*SD*	*mean comparisons (p)*	
FAST	/a/	.871	.067	.161		.798	.099	.624	
	/u/	.857	.062			.803	.088		
SLOW	/a/	.823	.101		<.001	.735	.118		<.001
	/u/	.774	.116			.700	.129		

Table E.6

Pairwise comparison results for the effect of vowel across rate and PoA for INT-R

INT-R						
/b/						
PoA*Rate	FAST			SLOW		
Vowel			/a/ vs /u/			/a/ vs /u/
	M	*SD*	*mean comparisons (p)*	*M*	*SD*	*mean comparisons (p)*
/a/	0.817	0.113	.023	0.760	0.144	.022
/u/	0.834	0.127		0.746	0.151	

INT-R						
/d/						
PoA*Rate	FAST			SLOW		
Vowel			/a/ vs /u/			/a/ vs /u/
	M	*SD*	*mean comparisons (p)*	*M*	*SD*	*mean comparisons (p)*
/a/	0.862	0.118	<.001	0.788	0.153	<.001
/u/	0.831	0.112		0.754	0.150	

INT-R						
/g/						
PoA*Rate	FAST			SLOW		
Vowel			/a/ vs /u/			/a/ vs /u/
	M	*SD*	*mean comparisons (p)*	*M*	*SD*	*mean comparisons (p)*
/a/	0.851	0.116	<.001	0.774	0.147	<.001
/u/	0.798	0.120		0.713	0.153	