

Lenition of Intervocalic Alveolar Fricatives in Catalan and Spanish

José Ignacio Hualde^a Pilar Prieto^b

^aDepartment of Spanish and Portuguese, University of Illinois at Urbana-Champaign, Urbana, Ill., USA; ^bICREA, Universitat Pompeu Fabra, Barcelona, Spain

Abstract

We offer an acoustic study of variation in the realization of intervocalic alveolar fricatives in Catalan and Spanish. We consider the effects of phonological inventory (Catalan has a distinction between /s/ and /z/ that Spanish lacks) and position in word (i.e. effects of word boundaries). An analysis of a corpus of Map Task interviews in Catalan and Spanish revealed that Spanish word-medial and initial intervocalic /s/ segments are shorter than in Catalan. Whereas our results are consistent with the predictions of theories incorporating functional principles (i.e. contrast preservation), we also consider other possible explanations of the facts. The analysis also revealed that Spanish word-final intervocalic /s/ segments are weaker along the two dimensions that we examined (duration and voicing) than their initial and medial counterparts. We suggest that this apparently morphological effect on lenition has an articulatory explanation in terms of gestural coordination.

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1 Introduction

The phenomenon with which we are concerned in this paper is the synchronic weakening of intervocalic alveolar fricatives in Iberian Spanish and Catalan. A reason to compare Spanish and Catalan is that these are two closely related languages that differ in the phonological status of voiced fricatives: whereas Catalan has a contrast between voiceless /s/ and voiced /z/, Spanish lacks the voiced phoneme /z/. We investigate the potential effects of this phonological difference on the phonetic weakening of /s/ in the two languages.

Contrast preservation has been claimed to be an important principle in phonology (Flemming, 1996; Łubowicz, 2003), which may condition the phonetic realization of segmental and suprasegmental phonological features (Ortega-Llebaria, 2004; Gussenhoven and Wang, 2014, among others). In particular, the claim has been made that lenition processes show an overwhelming tendency to avoid neutralization (Gurevich, 2004). The prediction that follows from this theoretical stance is that Catalan would show less weakening of intervocalic /s/ than Spanish.

In addition to inventory-driven effects, a second nonphonetic factor that we want to explore in this study is the possible effect of word boundaries on intervocalic lenition. Although our target tokens are all intervocalic, they differ in the presence and position of word boundaries. We compare sequences with word-internal /VCV/, word-initial /V#CV/, and word-final consonants /VC#V/. As we explain below, word position interacts with the possibility of having a phonological contrast in Catalan. Previous research (Torreira and Ernestus, 2012) and dialectal patterns lead us to hypothesize more lenition in /VC#V/.

In principle, the Neogrammarian hypothesis excludes the possibility of having morphological effects at the inception of a sound change and, by extension, in synchronic phonetic variation (see Joseph, 1999, discussed below in more detail). Our view is, however, that predicting a difference between /VC#V/ and the other two intervocalic contexts, word-initial and word-medial, is not really incompatible with this orthodox position, once we consider that there may be a difference in articulatory planning between /CV/ and /C#V/, so that the effect would not be purely morphological. The same reasoning would not apply, on the other hand, to /VCV/ versus /V#CV/, where gesture coordination can be assumed to be the same.

Before developing our hypotheses, we situate our investigation of /s/ lenition within recent research on intervocalic voicing in Spanish and other Romance languages. The phonetic weakening of intervocalic /s/ in Catalan and Spanish may be considered within a larger phenomenon affecting other voiceless consonants. A number of acoustic studies have shown that, especially in casual speech, the intervocalic voiceless stops /p t k/ have a tendency to voice and further weaken to approximants, in many Spanish varieties (Torreblanca, 1976; Machuca Ayuso, 1997; Lewis, 2001; O'Neill, 2010; Hualde et al., 2011; Torreira and Ernestus, 2011). This lenition is an incipient, optional phenomenon, much more common in spontaneous speech than in reading style and subject to substantial individual variation (Hualde et al., 2011). For instance, *la política* 'the politics' may be realized as [laβoliðiya]. From a historical point of view, this is a 'second round of voicing' in the evolution from Latin to Romance (Oftedal, 1985). Some previous work has shown that, in Spanish, optional intervocalic voicing also affects fricatives, especially /s/ (Torreblanca, 1976; Torreira and Ernestus, 2012; for the lenition of /f/, see Blecua and Rost, 2013). In particular, Torreira and Ernestus (2012) found that over a third of tokens of intervocalic /s/ extracted from a corpus of casual Madrid Spanish speech were realized as voiced during their entire duration.

The optional voicing of intervocalic /p t k/ is also found in Catalan, although perhaps with lesser intensity than in Spanish (see Hualde et al., 2010a for Majorcan Catalan, which is clearly more conservative than Iberian Spanish in this respect). To our knowledge, there has been no systematic study of the synchronic weakening of /s/ in this language.

In principle, it seems sensible to think that the voicing lenition of intervocalic /s/ may be part of the same phenomenon as the voicing of intervocalic stops. In this respect, we note that the historical voicing of intervocalic consonants in Western Romance ('first round of voicing') affected both stops and fricatives, as show in (1) with Catalan and Portuguese examples:

(1) Voicing of intervocalic obstruents in Western Romance

- Lat LUPA > Cat *lloba*, Port *loba* 'she-wolf'
- Lat ROTA > Cat, Port *roda* 'wheel'
- Lat AMĪCA > Cat, Port *amiga* 'friend, fem.'
- Lat CASA > Cat, Port *ca/z/a* 'house'

On the other hand, however, there are important differences between stops and fricatives. Whereas the voicing of intervocalic plosives can be taken as a unidirectional phenomenon (e.g., /ata/ > /ada/ is common in historical evolution, but /ada/ > /ata/ is not; see, however, Pape and Jesus, 2011 for European Portuguese), strident fricatives are subject to competing pressures, with both the voicing of intervocalic fricatives (e.g. /asa/ > /aza/), and the (unconditioned) devoicing of sibilants, /z/ > /s/, being natural, unremarkable phenomena. In fact, regarding examples like those in (1), in Spanish the evolution has been just like in Catalan and Portuguese for intervocalic /p t k/, but there has been a round-trip evolution for intervocalic /s/, which was voiced in Old Spanish, but devoiced again some centuries later, Lat /kása/ > OSp /káza/ > ModSp /kása/ (see, e.g., Penny, 2002, pp. 98–103). Voiced fricatives and affricates also underwent devoicing in several other Ibero-Romance languages, including varieties of Valencian Catalan (Wheeler, 2005, p. 23). (On reversible and nonreversible sound changes in Romance, see Recasens, 2002.)

The production of voiced fricatives, especially voiced strident fricatives such as /z/ and /ʒ/, is subject to opposing aerodynamic constraints, since the maintenance of voicing and the generation of a turbulent airstream make contradictory demands (Ohala, 1983, pp. 201–202). To solve this conflict, phonologically voiced fricatives may be produced as partially or completely devoiced, as frequently happens in English (Smith, 1997). Diachronically, this may lead to the recategorization of voiced fricatives as voiceless (see Fontanella de Weinberg, 1979, 1987, pp. 144–150; Rohena-Madrado, 2013, for the devoicing of /ʒ/ in Argentine Spanish). The other solution to the incompatibility between voicing and stridency is to maintain voicing at the cost of reducing friction (Solé, 2002). This solution is also widely attested both in diachronic processes and in synchronic allophony. A well-known example is rhotacism in Pre-Latin, e.g. **flō[s]ēs* > **flō[z]ēs* > *flō[r]ēs* ‘flowers’ (Allen, 1978, p. 35; Trask, 1996, pp. 78–82). (Rhotacism of /s/ before a voiced consonant is found dialectally both in Spanish, see Moreno Fernández, 1996, p. 218, and in Catalan, see Recasens, 1996; Pons Moll, 2007, pp. 157–167.) Thus, constraints favoring assimilation in voice of intervocalic /s/ compete with other constraints which disfavor [z]. Given these differences in the voicing of stops and fricatives, it is not obvious that the same pattern of lenition should be predicted for intervocalic /s/ as has been found in other studies that have examined intervocalic /p t k/ in the same languages. Thus, although we see the voicing of intervocalic /s/ as part of the same phenomenon that affects voiceless stops in Spanish and Catalan, we do not necessarily expect to find the same results as in studies that have examined the voicing of /p t k/. It seems that, in principle, the prediction should be that, compared to the voicing of /p t k/, full voicing of /s/ (as opposed to its partial voicing) would be less common, because of the opposing aerodynamic constraints that we have mentioned. However, we note that Torreira and Ernestus (2012) find a percentage of fully voiced tokens of intervocalic /s/ (34%) that is very similar to that reported in Torreira and Ernestus (2011) for intervocalic /p t k/ (32.7%) in the same corpus of casual Madrid Spanish speech. In this paper, we are not able to further test these facts, since we are only concerned with alveolar fricatives.

2 Main Research Questions and Predictions

This study addresses two main research questions concerning the weakening of intervocalic /s/: (1) whether the principle of preservation of phonological contrast has

an effect, addressed by comparing Spanish and Catalan, and (2) whether word boundaries have an effect, addressed by comparing consonants in different positions in the word within each language. Both questions thus involve the possible effect of nonphonetic (i.e. phonological or morphological) factors on phonetic lenition.

In Spanish, there is no voice opposition among the fricatives. All fricatives are phonologically voiceless, although a well-documented phenomenon is their voicing before a voiced consonant, e.g. /mismo/ [mízmo] ‘same’ (see Schmidt and Willis, 2011 for a recent study).

In Catalan, on the other hand, there is a phonological contrast between /s/ and /z/. This phonemic contrast is, however, restricted to onset position and essentially limited to the word-internal intervocalic position (e.g. *caça* /kásə/ ‘hunt’ vs. *casa* /kázə/ ‘house’). Word-initially there is also a phonemic contrast, but /z/ is only found in a handful of, mostly technical, words, e.g. *zero* ‘zero’, *zona* ‘zone’ (for which devoicing is common, Recasens, 1993, p. 173). Word-finally, the contrast is neutralized, and [s] and [z] are found in complementary distribution: [s] appears before a voiceless segment or pause, e.g. *mé[s] temps* ‘more time’, *mé[s]* ‘more’, and [z] before a voiced consonant or vowel, e.g. *mé[z] dies* ‘more days’, *mé[z] amics* ‘more friends’ (see, e.g., Wheeler, 2005, pp. 148–149, 162–163).

Our first research question is thus related to contrast preservation as a possible factor in the phonetic realization of /s/ in Catalan versus Spanish. If contrast preservation acts as a phonological restriction on the weakening phenomenon, we would expect for word-initial or word-medial /s/ to show less voicing and greater duration in Catalan, where it contrasts with /z/ phonemically, than in Spanish, where it does not. Regarding the predicted effects on duration, as is well known, there is an inverse correlation between voicing and duration, so that phonologically voiced obstruents are shorter than their phonologically voiceless counterparts (Lehiste, 1970; for /s/ and /z/ in English, see Smith, 1997).

As explanations for phonetic patterns, inventory-driven, functional principles are, by their very nature, more controversial than articulatory, acoustic or aerodynamic factors. Our view is that one way to determine the efficacy of such principles in explaining synchronic phonetics and sound change is by conducting comparative studies like the present one and examining, first of all, whether the facts are compatible with the predictions stemming from the functional principle and, secondly, whether there could be alternative explanations. The evaluation of the cumulative evidence of a number of studies of this type could then be used to decide the question of the reality of contrast preservation and similar principles. That is, we take the principle of preservation of contrast as a hypothesis to be tested.

Our second research question concerns word position. As mentioned in the introduction, the Neogrammarian view excludes the possibility of the presence of morphological boundaries as a conditioning effect in sound change. As Joseph (1999, p. 6) explains, ‘if sound change is a purely mechanical adjustment in pronunciation triggered by the phonetics of connected speech, that is by purely physiological (articulatory or perceptual) effects, then it follows that whenever those conditions obtain – whether in a word or in a phrase, whether in word-medial or in word-initial position, whether at a morpheme boundary or within a monomorphemic word – the change would take place.’

Several recent studies have compared the realization of phonological stops in the contexts /VCV/ and /V#CV/ in Spanish and other Romance languages. In general, the

difference between these two contexts appears to be small or nonexistent and, thus, in accordance with the Neogrammarian hypothesis of no morphological conditioning in lenition processes. Hualde et al. (2011) did not find an effect of word boundaries on either the voicing of intervocalic /p t k/ or the degree of constriction of /p t k b d g/ in Iberian Spanish. Eddington (2011) studied the allophony of /b d g/ in Spanish, including speakers from several dialects, and reported that intervocalic [β] and [ð] were less constricted when word-medial than when word-initial, but he found no effect for [ɣ]. Another study of the allophony of /b d g/ in Spanish, Carrasco et al. (2012), found a small statistical effect of word boundaries on the degree of constriction of these consonants in Costa Rican Spanish, but these authors did not find this effect in their Madrid Spanish corpus. Hualde and Nadeu (2011) examined the weakening of intervocalic /p t k/ in Rome Italian and reported comparable amounts of weakening in word-medial and word-initial position.

The studies just reviewed, on the allophony of /p t k/ and /b d g/, considered only the presence of a word boundary immediately before the consonant, that is, they compared /VCV/ with /V#CV/. This is understandable since the consonants that were examined are rare word-finally in Spanish (and Italian). By extending the investigation to /s/, on the other hand, we can also consider the sequence /VC#V/, since /s/ is frequent word-finally. In a recent study of casual Madrid Spanish speech, Torreira and Ernestus (2012) did, in fact, find more lenition of /s/ in word-final intervocalic position than in other intervocalic contexts.

Our hypothesis is that intervocalic /s/ will be more reduced word-finally, in /Vs#V/, than in other positions, as Torreira and Ernestus (2012) found, resulting in shorter duration and more voicing. The disagreement with the Neogrammarian view is only apparent. We suggest that the difference between /Vs#V/, on the one hand, and /VsV/ and /V#sV/, on the other, is not purely morphological, but also involves differences in articulatory planning. In word-final position, lexical syllabic affiliation gives a different gestural coordination than in /VsV/ and /V#sV/, even if there is postlexical resyllabification, as it is usually assumed for Spanish.

Regarding the possible role of word-internal morphological boundaries, which we do not test here, Torreira and Ernestus (2012) compared the realization of /s/ when it is a suffix by itself (i.e., plural of nouns, adjectives and determiners or second person singular of verbs, e.g. *casa-s* ‘houses’, *tiene-s* ‘you have’) with other instances of word-final /s/, without finding a significant difference. (Instead, they found some, relatively weak, support for the hypothesis of greater reduction of redundant suffixes.) These results are thus also compatible with the hypothesis that morphological structure does not have a direct effect on phonetic realization.

Besides the results in Torreira and Ernestus (2012), other well-known facts of Spanish also show that in this language consonants tend to be weaker in word-final position, even when they are prevocalic. In particular, in addition to possible voicing and reduction in duration, another common form of lenition of /s/ in many Spanish varieties, including, to some extent, Madrid Spanish, is its aspiration and deletion. Most commonly across Spanish varieties, the aspiration and/or deletion of /s/ affects this segment in syllable-final position. Nevertheless, in many Spanish dialects with frequent aspiration, word-final /s/ is subject to aspiration and deletion even when it precedes a vowel, and, presumably, is resyllabified as an onset (Harris, 1983). That is, in prototypical aspirating dialects, /s/ may be realized as [h] in, for instance, *más oro* ‘more gold’, but not in *masa* ‘dough; mass’, where it is word-internal. (There are some

dialects where word-internal and word-initial prevocalic /s/ is also subject to lenition, see, e.g., Lipski, 1986; for recent studies of lenition of /s/ in dialects with a high incidence of aspiration, see, among others, Brown, 2011, and File-Muriel and Brown, 2011.) We use these facts, from Spanish dialectology, as motivation for the hypothesis of greater weakening in /Vs#V/ than in /VsV/ or /V#sV/ also when /s/ is produced as an alveolar fricative. In the Discussion section we return to the topic of /s/ aspiration and its relation to the phenomenon that we investigate in our study.

It should be noted that, in Madrid Spanish, aspiration of /s/ is not uncommon before certain consonants, but it is infrequent in the prevocalic /Vs#V/ context. Regarding its sociolinguistic distribution, aspiration of /s/ in Madrid Spanish is especially rare in the speech of educated women, which is the demographic group to which all the participants in our study belong. In a sociolinguistic study of /s/ aspiration in Madrid Spanish, Momcilovic (2009, p. 44) reports less than 3% of aspirated tokens of /s/ in the context /s#V/ in the conversational speech of educated female speakers, who are the most conservative speakers in this respect. Our hypothesis is, again, that even if word-final /s/ is realized as an alveolar fricative (and would be coded as not aspirated in a perceptual sociolinguistic study), it may be relatively reduced in comparison to word-initial and word-medial prevocalic tokens.

Regarding word-position effects, then, we expect /VsV/ and /V#sV/ to pattern together and /Vs#V/ to undergo greater lenition. As we have explained, we predict that morphological boundaries will have an effect on pronunciation only if they affect articulatory planning.

3 Methods

3.1 Participants and Speech Materials

For this study we have analyzed audio recordings of directed conversational speech (Map Tasks) that were previously collected for unrelated projects, the *Interactive Atlas of Catalan Intonation* (Prieto and Cabré, 2007–2012) and the *Interactive Atlas of Spanish Intonation* (Prieto and Roseano, 2009–2013). We have analyzed 13 Map Tasks for Central Catalan (26 speakers) and 8 Map Tasks for Madrid Spanish (16 speakers). All participants of both languages were educated women between 20 and 50 years of age who grew up in the region where the recording took place. The audio recordings, as well as orthographic transcriptions and the maps used for the task, can be accessed from the corresponding atlas webpages.

The data set used for this investigation consisted of conversational speech that was recorded (for the interactive atlas of intonation of each of the two languages) by having pairs of speakers in each language perform a Map Task. The Map Task methodology is a well-established procedure for obtaining semispontaneous, unscripted speech (Brown et al., 1983; Anderson et al., 1991). In a Map Task, speakers are recorded in pairs as they perform together a goal-oriented activity.

Each of the two participants in each recording had a map of an imaginary town including buildings and other specific elements such as fountains and monuments. A route was drawn on the map of one of the two participants, who had the role of instruction-giver. A version of the same map held by the other participant differed from that of the instruction-giver in that it did not show the route to be followed, in addition to several other details. Differences in details between the two maps are intended to elicit discussion.

The total duration of the 13 Catalan Map Task dialogs is 94 min, distributed as follows, by the name of the town where the data were collected: Banyoles (2 Map Tasks, 20 min), Barcelona (2 min), Berga (4 min), La Garriga (7 min), Manresa (7 min), Mataró (11 min), Ripoll (4 min), Santa Coloma (5 min), Solsona (7 min), Valls (8 min), Vic (8 min) and Vilafranca del Penedès (6 min). These are all towns located in the Central Catalan area. As mentioned before, both participants in each recording were natives of the town where the recording took place. The total duration of the 8 Madrid Spanish

Map Task dialogs adds up to a total of 60 min. All Madrid speakers were living in Madrid and were born either in Madrid or in the surrounding area within the province.

In the selection of participants and speech materials we have been constrained by the availability of recorded data, since, as mentioned, our materials are from preexisting corpora. Nevertheless, in our estimation, the selected materials are fully adequate for the comparison that we want to establish between Madrid Spanish and Central Catalan. All speakers of the two languages are educated women and the speech task in which they engage is the same. This provides an important control. In the case of Catalan, a factor to consider is bilingualism. In Catalonia, different speakers may have different degrees of dominance in Catalan and Spanish or may use the two languages with different frequency. Although the towns where the interviews were conducted vary in their size and their overall social use of the two languages, all speakers that were recorded for the *Interactive Atlas of Catalan Intonation* were selected because they were strongly dominant in Catalan.

An additional advantage of using these Spanish and Catalan corpora for our study is that the data are available to other researchers for replication and further testing.

3.2 Data Segmentation and Coding

Data segmentation was performed with Praat (Boersma and Weenink, 2013). We labeled all instances of intervocalic /s/ and /z/ in Catalan and all instances of intervocalic /s/ in Spanish. That is, for Catalan all intervocalic instances of <-ç->, <-ss->, <(-)c-> before <i, e>, and <s-> were labeled as /s/ (e.g. *passo* ‘I pass’, *edifici* ‘building’, *podria semblar* ‘it could seem’, no examples containing <ç> were found); all instances of <-s-> and <z> were labeled as /z/ (e.g. *gasolinera*, no instances of orthographic <z> were found), and word-final <-s>, <-ç> were labeled as /S/ (noncontrastive alveolar fricative, e.g. *tires amunt* ‘you go up’). For Madrid Spanish, the orthography/phoneme correspondence is straightforward: all intervocalic instances of <s>, and only those, were labeled as /s/.

Regarding Catalan, Recasens (1993, pp. 173–175) points out that there is some dialectal or individual variation in the pronunciation of some specific lexical items as containing /s/ or /z/. In every case, we have followed the phonological category suggested by the standard spelling of the word for our labeling. We can thus not exclude the possibility that a few tokens may have been misclassified with respect to the phonological intention of the speaker.

We discarded tokens that were disrupted by laughter, disfluencies and intrusive overlapping speech, as well those surrounded by voiceless vowels. A total of 974 tokens of intervocalic /s/ and /z/ were labeled for the Central Catalan corpus and a total of 648 tokens of intervocalic /s/ were labeled for the Madrid Spanish corpus.

Segmentation was done manually in Praat. To determine the initial and final boundaries of the fricative we considered the onset and offset of aperiodic energy in the sound wave. All segmentation for both Catalan and Spanish was performed by the same research assistant, who was not informed of the specific research hypotheses. Given the fact that all the data from both languages were segmented by the same person using the same criteria, we are confident about the reliability of the segmentation procedure. Tokens were also tagged as initial, medial or final in the word, as shown in (2) with Spanish examples from the corpus:

(2) Examples of intervocalic /s/ tokens in Spanish

Initial	=	V#sV	<i>como si</i>	‘as if’
Medial	=	VsV	<i>casa</i>	‘house’
Final	=	Vs#V	<i>más abajo</i>	‘further down’

The data were subjected to analysis using both binary and continuous parameters. First, segmented tokens were labeled as fully voiced if they presented regular pulses and uninterrupted pitch in the Praat display. This was done by visual inspection. This allowed for a binary classification of tokens as either fully voiced or not. Secondly, two types of information were automatically extracted from the TextGrid. One type of information that was extracted is fricative duration, i.e., the distance in time between the onset and the end of aperiodic energy, signaling friction. The second type of information that was obtained is the percentage of ‘voiced frames’ within the target segments. For this we used a script written by Paul Boersma, *analyseFricatives.praat*, which is included as an appendix in Rivas (2006). This script automatizes some of the options available in Praat. Using this algorithm, frames with a local harmonics-to-noise ratio above 0.45/0.55 (= -0.9 dB) are regarded as voiced. The script

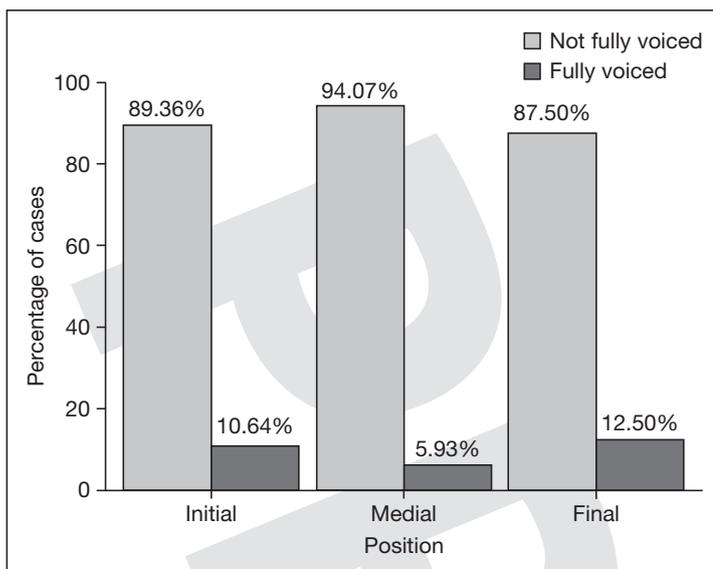


Fig. 1. Percentage of fully voiced tokens of /s/ by position in our Spanish corpus.

returns a value of 1 when all frames within the segment show a harmonics-to-noise ratio above this threshold. A value of 0 indicates that no frames within the segment were classified as voiced by the algorithm. In this script 30 ms of the vowel are taken into account at both sides of the fricative for the ‘voiced frames’ report. For this reason the value that is returned is never zero in our data.

We have used this script because it makes the results more reproducible, since the pitch floor and ceiling and all other settings are under full control. The script provides a report of the percentage of frames that are strongly voiced.

3.4 Statistical analysis

For all statistical analyses, we used mixed-effects linear regression models (GLMMs) with SPSS. We applied the same models to two main response variables (‘voiced frames’ and duration). In both analyses, the model included word Position [with three levels: (word)-Initial, (word)-Medial, and (word)-Final], and Language (with two levels: Catalan and Spanish), as fixed factors, and Speaker and Word identity as random factors. We are concerned with the fixed effects (which were explored separately), plus the potential interactions between word Position and Language. Only statistically significant predictors, as well as significant interactions, are retained in the reported models.

4 Results

4.1 Number of Fully Voiced Tokens

Full voicing of intervocalic /s/ is relatively uncommon in our data. In our Madrid Spanish corpus, only 8.3% ($n = 54$) of all analyzed tokens of /s/ ($n = 648$) were manually identified as fully voiced (which coincides exactly with the number of tokens for which the script returned a value of 1 under ‘voiced frames’): Initial = 15/141 (10.6%), Medial = 22/371 (5.9%), Final = 17/136 (12.5%). Figure 1 shows the distribution of fully voiced tokens of /s/ by position in Spanish. The greatest percentage of fully voiced tokens is thus found word-finally.

The percentage of fully voiced tokens that we have obtained is substantially lower than the 34% reported in Torreira and Ernestus (2012). The difference between the results of both studies is most likely to be attributed to the more casual style that those

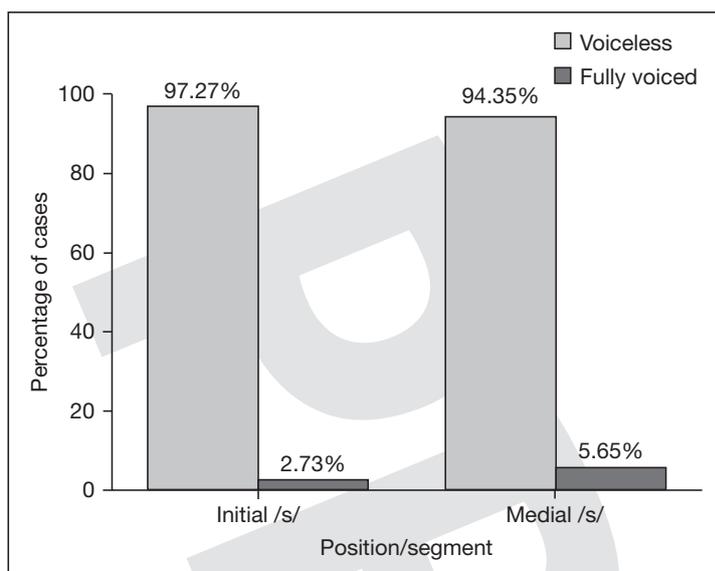


Fig. 2. Percentage of fully voiced tokens of /s/ by position in our Catalan corpus.

authors analyzed (in addition to methodological differences between the studies). However, it is important to note that Torreira and Ernestus (2012) report a high degree of interspeaker variation, so that this may also be a factor.

In the case of Catalan, the percentage of fully voiced intervocalic /s/, excluding word-final intervocalic fricatives, is much lower, only 4.1%: Initial 7/256 (2.7%), Medial 13/230 (5.6%; fig. 2).

To complete the picture, we must consider the realization of /z/ and word-final alveolar fricatives in Catalan. As mentioned before, although in Catalan a /s/-/z/ contrast obtains both word-initially and word-medially, word-initial /z/ is found in only a handful of words. As it happens, in our corpus no instances of word-initial /z/ were found. All references to /z/ in Catalan will thus be to word-medial intervocalic tokens. For word-final tokens, where the voiced/voiceless contrast does not obtain, we use the symbol /S/, as already mentioned. Inspection of the data shows that both /z/ and /S/ were very often partially devoiced, although fully voiced realizations were more common than partially devoiced ones for both /z/ (59.4%) and /S/ (60%; fig. 3).

4.2 Voiced Frames

In the presentation of the voiced frames and duration results, descriptive graphs (boxplots) will be followed by more detailed statistical analyses.

The boxplots in figure 4 show the percentage of voiced frames of intervocalic /s/ tokens in Spanish and of /s/, /S/ and /z/ tokens in Catalan (ranging from 0 to 1), as a function of the position of the consonant within the word (initial, medial, final) in the Spanish and Catalan Map Task corpora. In the boxplot graphs, the horizontal line within the boxes represents the median of the entire distribution, and the boxes display the interquartile range, i.e. observations between the 25th and the 75th percentiles. Whiskers extend to the most extreme of the observations lying no further away than 0.5 of the length of the box. Observations beyond those points are outliers.

Let us comment on the results in figure 4 separately by the potential effects of word position and language. The effects of word position are most apparent in Catalan. As expected, the highest values of voiced frames correspond to the underlying

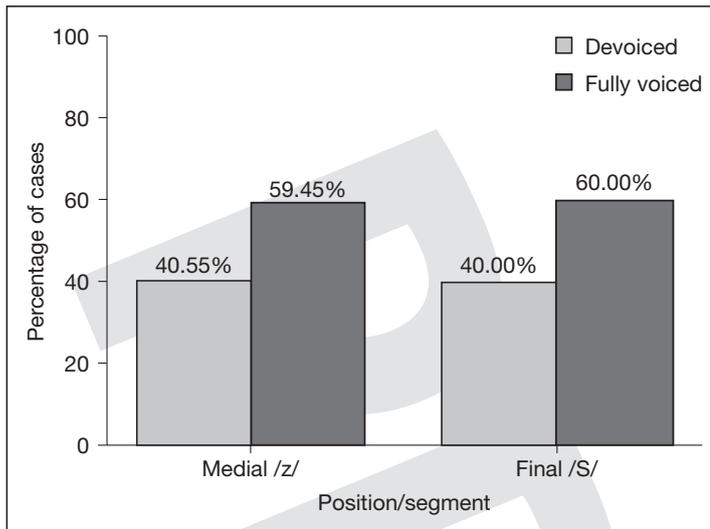


Fig. 3. Percentage of fully voiced and partially devoiced tokens of /z/ and intervocalic word-final /S/ in our Catalan corpus.

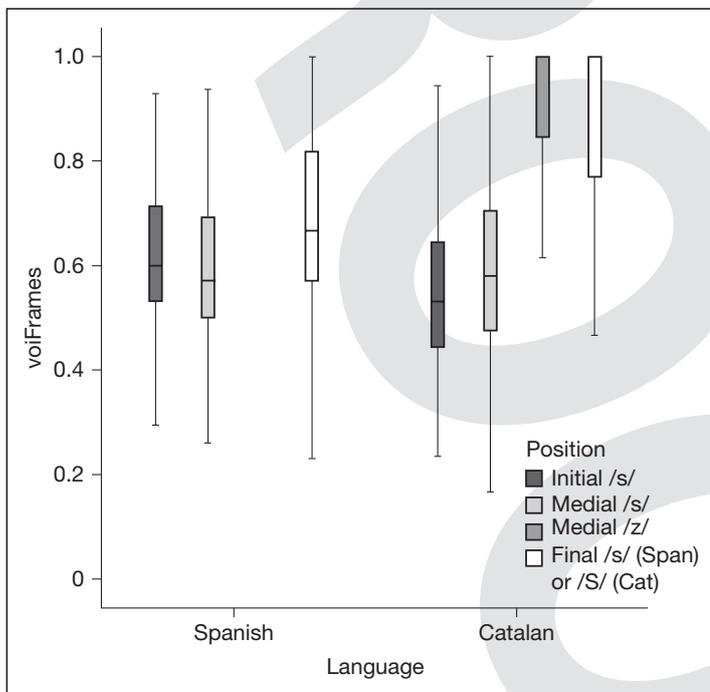


Fig. 4. Percentage of voiced frames of intervocalic /s/ segments of Spanish and /s/, /z/ and /S/ segments in Catalan (ranging from 0 to 1) as a function of the position within the word (initial, medial, final) in the Spanish and Catalan Map Task corpora; 30 ms of the vowels on both sides of the fricative are included in computing voiced frames.

word-medial /z/ in Catalan and to word-final intervocalic /VS#V/. Thus, our results confirm the traditional phonological understanding of the facts; namely, that in Catalan word-final alveolar fricatives are realized as voiced when followed by a vowel in the next word. A phonological interpretation is that the neutralization between /s/ and /z/ in word-final position is manifested as phonemic /z/ when a vowel follows in the speech chain.

For Spanish, the boxplots show that word-final intervocalic /s/ (/Vs#V/) is somewhat more voiced than word-medial or word-initial /s/ (/VsV/ and /V#sV/). On the other hand, word-final /s/ in Spanish is clearly not as voiced as the corresponding

segment in Catalan. Unlike in Catalan, one cannot speak of a phonological rule of voicing for word-final /s/ before a vowel.

In order to investigate the effects of the different factors on /s/ voicing in a single statistical analysis for both languages, we eliminated the Catalan underlying /z/ tokens (medial /z/ in the graph) from the data. We fitted a mixed-effects regression model (GLMM) to the data set, considering the proportion of voiced frames as a response variable, Position in the word (Initial, Medial, Final) and Language (Catalan, Spanish) as fixed factors, and Speaker and Word identity as random factors. A main effect for Position in the word, $F(2, 1.289) = 139.794$, $p < 0.001$, was found, as well as a marginal main effect of Language, $F(2, 1.289) = 3.660$, $p = 0.056$, and a significant interaction between Language and Position in the word, $F(2, 1.289) = 56.254$, $p < 0.001$, meaning that the effect of word position was different across the two languages.

To investigate group differences in the interaction of Language and word Position, Bonferroni post hoc pairwise comparisons were extracted from the model. On the one hand, these comparisons show that voice ratios of intervocalic /s/ are significantly different between the two languages, but only in final position (Catalan vs. Spanish, at $p < 0.001$). For Catalan, we find significant differences in voice ratios between the three pairs of word positions. As expected, the greatest amount of voicing is found for word-final, noncontrastive /S/: Final versus Initial, at $p < 0.001$; Final versus Medial, at $p < 0.001$. In addition, word-medial consonants have more voicing than initial ones: Initial versus Medial, at $p < 0.001$. For Spanish, the only comparison that reaches significance, at $p < 0.001$, is Final versus Medial, with final consonants being more voiced. The greater voicing of word-final consonants is in agreement with the findings in Torreira and Ernestus (2012).

4.3 Duration

The boxplots in figure 5 show the duration (in ms) of intervocalic /s/ in Spanish and intervocalic /s/, /z/ and /S/ in Catalan as a function of the position of the consonant within the word (initial, medial, final) in the Spanish and Catalan data (indicated on the x axis). As before, medial /z/ represents the word-medial phonological /z/ category in Catalan and /S/ is used for word-final fricatives in this language.

Considering first the Spanish data, visual inspection of the boxplots shows that in Spanish word-final intervocalic /s/ (in /Vs#V/) is shorter than word-medial or word-initial /s/ (in /VsV/ and /V#sV/). In the Catalan data, as expected, underlying word-medial /z/ and final intervocalic /S/ (/VS#V/) display the shortest durations. The comparison between Spanish and Catalan indicates that word-initial and word-medial intervocalic /s/ are shorter in Spanish than in Catalan.

The significance of the comparisons was tested via a regression analysis. As before, in order to investigate the different sources of variability affecting the duration of intervocalic /s/ in a single analysis for the two languages, we eliminated the Catalan underlying /z/ tokens (medial /z/ in the graph) from the data set. We fitted a mixed-effects regression model (GLMM) to this data set, including the variables in section 3.4, i.e. Duration as response variable, Position in the word (Initial, Medial, Final) and Language (Catalan, Spanish) as fixed factors, and Speaker and Word identity as random factors. Regarding the fixed factors, a main effect for Position in the word, $F(2, 1.267) = 139.794$, $p < 0.001$, was found, as well as a significant interaction between Language and Position, $F(2, 1.267) = 39.460$, $p < 0.001$, meaning that the effect of word Position was different across the two languages.

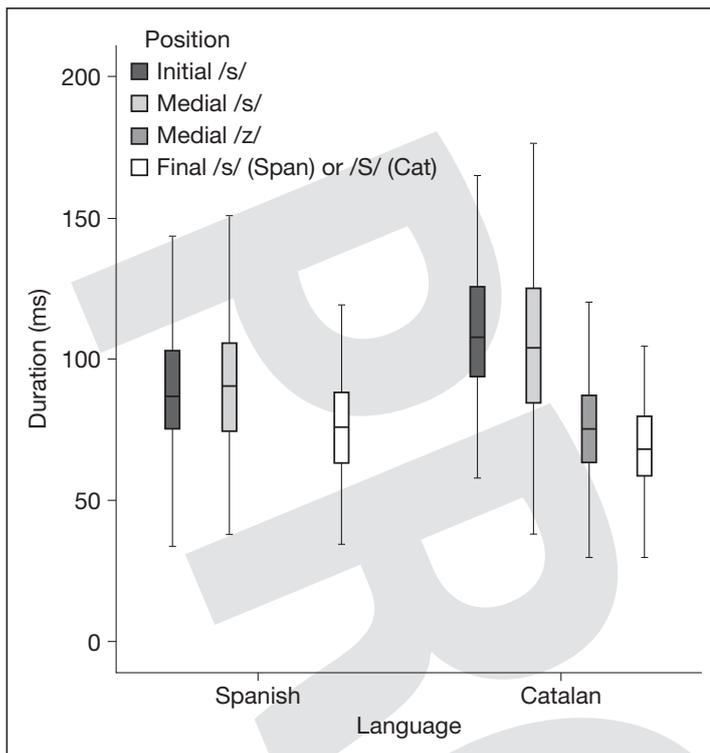


Fig. 5. Duration (in ms) of intervocalic /s/ segments of Spanish and /s/, /z/ and /S/ segments in Catalan as a function of the position within the word (initial, medial, final).

To investigate the direction of the interaction Language by Position, Bonferroni post hoc pairwise comparisons were extracted from the model. These comparisons show that the duration of intervocalic /s/ is significantly different in Catalan versus Spanish, across the three word positions. In Final position, Catalan word-final /S/ presents shorter duration than Spanish /s/ ($p < 0.001$). In Medial position, on the other hand, Catalan /s/ is longer than Spanish /s/ ($p < 0.001$). In Initial position as well, Catalan /s/ is longer than Spanish /s/ ($p < 0.001$).

The comparisons among positions within each of the two languages do not return identical results. In Catalan, we find a significant difference in duration between the three pairs of word positions (Final vs. Initial, at $p < 0.001$, Final vs. Medial, at $p < 0.001$, and Initial vs. Medial at $p < 0.001$). From longest to shortest the duration hierarchy is Initial > Medial > Final. Nevertheless, regarding the Initial versus Medial comparison, some caution is in order in the interpretation of this significant result, since the boxplots in figure 5 show a great degree of overlap between the two groups.

In Spanish, on the other hand, only two comparisons are significant in our statistical analysis, namely Final versus Initial, at $p < 0.001$, and Final versus Medial, at $p < 0.001$. That is, in Spanish there is no difference in duration between word-initial and word-medial tokens of /s/, but word-final tokens are significantly shorter than the rest. Thus, the duration ranking that we find in Spanish is Initial, Medial > Final. The shorter duration of final /s/ in Spanish is consistent with the finding, reported above, that this is also the position that shows the greatest amount of voicing.

In sum, the regression modeling of the duration results points to two main conclusions, namely: (a) that intervocalic /s/ durations pattern differently in Spanish and in Catalan in the three word positions, with /s/ being longer in Catalan than in Spanish, except that word-final Catalan /S/ is shorter than word-final Spanish /s/, and (b) that,

within each of the two languages, consonants are shortest in final position. This is true both in Catalan, where final sibilants are phonologically neutralized in voice, and in Spanish. In Catalan, initial /s/ is slightly longer than medial /s/, which in turn is longer than final /S/. In Spanish, /s/ durations in word-final position are significantly shorter than in word-medial and word-initial position. There is no difference between initial and medial tokens of /s/ in Spanish. These results lend initial support both to the hypothesis of less lenition under phonemic contrast in Catalan and to the hypothesis of greater lenition in word-final position.

5 Summary of Results

Our study on the lenition of alveolar fricatives in Spanish and Catalan has produced two main findings. Regarding the Catalan versus Spanish comparison, our results show that reduction of (non-word-final) intervocalic /s/ is rather more pervasive or intense in Madrid Spanish than in Central Catalan. In particular, both word-initially and word-medially, intervocalic /s/ is significantly longer in Catalan (where it contrasts with /z/) than in Spanish (which has no /z/). Also, about twice as many fully voiced tokens of /s/ were found in Spanish as in Catalan.

Our second research question was related to the possible effects of word boundaries on lenition. Our main finding in this respect is that intervocalic /s/ is weaker word-finally than in other positions in the word, as manifested by our duration and voicing measurements. This is true both in Catalan and in Spanish. In Catalan this is an unremarkable finding, since /s/ and /z/ neutralize word-finally and the result of the neutralization before a vowel-initial word is generally taken to be voiced. Interestingly this is also true in Spanish, where intervocalic /s/ is shortest and has the greatest amount of voicing in word-final position (although, regarding voicing, the statistical analysis returned a significant result only for the Final vs. Medial comparison), including the greatest percentage of fully voiced realizations. As mentioned, this is in agreement with the findings in this respect in Torreira and Ernestus (2012). As these authors note, this result, which we have replicated, is also consistent with a tendency for word-final /s/ to be aspirated or elided in many Spanish dialects, even when, as in our study, it precedes a vowel in the following word.

In the next section we consider possible explanations for our findings, regarding differences both between the two languages and across positions in the word.

6 Discussion

6.1 Realization of Intervocalic /s/ in Spanish versus Catalan

A main finding of our study is that intervocalic /s/ has a stronger, less lenited, realization in Catalan than in Spanish. Catalan intervocalic /s/ is longer than in Spanish and is less frequently realized as fully voiced. These results are as predicted by contrast preservation theory (e.g. Gurevich, 2004). In this view, the explanation for the stronger realization of intervocalic /s/ in Catalan than in Spanish would be that, in Catalan, /s/ is in phonemic contrast with /z/. Maintenance of the phonological contrast would, thus, disfavor lenition.

The role of functional principles such as contrast preservation, dispersion and functional load in sound change and synchronic phonology remains controversial. One reason for skepticism regarding the relevance of a principle of contrast preservation is that phonemic neutralization is, in fact, rampant in phonological evolution (see, e.g. Hock, 1991, pp. 150–151). For a recent defense of functional principles in sound change, see, however, Wedel (2012) and Wedel et al. (2013). See also Boersma (1998) on constraint interaction in functional phonology.

Whereas the difference that we find between Catalan and Spanish is consistent with the principle of contrast preservation, we must consider whether there could be alternative explanations of the facts that do not require appeal to functional principles.

A similar case to that studied in this paper is presented by the allophony of /b/ in different Catalan dialects, which has been the object of recent investigation. Some Catalan dialects, such as Majorcan Catalan, have a phoneme /v/ that is not present in most other Catalan varieties. It has been noted that, in dialects with a /v/-/b/ contrast, the phoneme /b/ tends to be realized as a voiced stop [b] in contexts where in dialects without this contrast it is generally lenited to an approximant [β] (Rafel, 1976, p. 62; Recasens, 1971/1975, 2009, pp. 131–132). Several authors have explained this fact by appealing to the principle of contrast preservation (Recasens, 1991; Wheeler, 2005).

In a recent study employing acoustic correlates of degree of constriction, Hualde et al. (2010a) found that, indeed, /b/ in contexts of lenition is more constricted in Majorcan than in Central Catalan, as other authors had observed. In addition, within Majorcan Catalan, /b/ is more constricted than /d/ and /g/. As an alternative to contrast preservation, the authors suggest that the explanation for the difference between the two dialects could also be that Majorcan Catalan preserves a less advanced stage in the historical weakening of intervocalic stops. They appeal to aerodynamic explanations to account for the difference across places of articulation. Recasens (2014, pp. 106–107) also discusses several possible explanations, besides contrast preservation, that may account for the allophony of /b/ in different Catalan varieties with and without an independent phoneme /v/. In general, before accepting the validity of a functional principle, it seems sensible to consider whether there could be alternative explanations.

Here we will thus consider other reasons that may explain the difference between Catalan and Spanish that we find. In the case at hand, it is important to note that the reason why the two languages differ at the phonological level in this respect is precisely that modern Spanish has given up an older contrast between /s/ and /z/ (as mentioned in section 1). We cannot then exclude the possibility that Spanish /s/ is weaker because it derives diachronically from the merger of earlier /s/ and /z/. Even if the two formerly contrasting phonemes /s/ and /z/ merged into a single phoneme /s/, the allophonic realization of this phoneme may now include part of the phonetic space of both earlier phonemes. That is, the variation that we are documenting in the realization of Spanish /s/ (including relatively short and voiced tokens) may have been present from the very beginning of the merger and may be a consequence of it. Under this interpretation, it would not be the case that Catalan /s/ resists weakening, because of contrast preservation; but, rather, that Spanish /s/ is weaker because of its phonological ancestry.

In addition, at this stage in our investigation, we cannot exclude the possibility that Spanish may simply display a greater tendency than Catalan for all voiceless obstruents to undergo reduction, regardless of other considerations. In this respect, it seems relevant to note that Hualde et al. (2010b), in an unpublished study, report a considerable difference between Iberian Spanish and Majorcan Catalan in the extent to which intervocalic /p t k/ undergo voicing: in their Spanish corpus, 36% of all tokens of intervocalic /p t k/ were realized as either fully or partially voiced versus only 17% in a similar corpus of Majorcan Catalan. Central Catalan remains to be examined.

In order to determine the possible role of contrast preservation in the lenition of /s/, future work could thus investigate the production of all shared voiceless fricative and plosive phonemes /f s p t k/ in comparable corpora of Spanish and Central Catalan (the affricate /tʃ/, which is also shared by both languages, does not seem to voice in

Iberian Spanish, although it is frequently voiced in Canary Island Spanish, where it has a more retracted realization, with less friction; Trujillo, 1980). The hypothesis of contrast preservation would predict that, even if, when compared to Catalan, Spanish shows a greater general tendency to lenite its intervocalic voiceless obstruents, the difference between the two languages should be greater for /s/ than for other phonemes (due to the presence of /z/ in Catalan, but not in Spanish).

In sum, whereas our experimental results are consistent with the predictions of the principle of contrast preservation, we cannot discard alternative explanations that do not appeal to this functional principle. A more extensive study of intervocalic lenition in the two languages may shed light on this issue.

Finally, we would like to point out that, as mentioned above, in Catalan, in some lexical items we find dialectal or individual variation in their realization with /s/ or with /z/ (Recasens, 1993, pp. 173–175). In particular, some words like *impressora* ‘printer’ and *disseny* ‘design’, in which the standard spelling suggests /s/, are systematically realized with /z/ instead, by some speakers. In the Catalan corpus that we have analyzed, although complete voicing of /s/ is very rare, we did find 20 tokens of fully voiced /s/ (see section 4.1). For instance, if we choose the lexical item with the greatest number of fully voiced realizations, out of 29 tokens of the form *passes* ‘you pass, go’ in our corpus, 7 were produced as fully voiced. The occurrence of ‘unintended’ fully voiced tokens of /s/ may lead to phonemic recategorization in specific lexical items, as envisioned in Ohala’s (see, e.g. 1974) framework. That is, contrast preservation, in the best of cases, cannot be understood as an absolute principle, preventing phoneme recategorization in specific lexical items.

6.2 Word-Position Effects

Regarding our second main result, the weaker character of word-final /s/, which confirms the findings in Torreira and Ernestus (2012), several facts may also explain it. First of all, in terms of articulatory planning, very likely there is an important articulatory difference between, on the one hand, /VCV/ and /V#CV/, and, on the other, /VC#V/. In the former case, the consonant is syllabified at the onset of the syllable, and is thus timed to start in phase with the following vowel (Nam et al., 2009), whereas in /VC#V/ lexical syllabic affiliation may result in a different gestural coordination, even if, as it is generally assumed for Spanish and Catalan, there is postlexical resyllabification. In other words, resyllabification may be incomplete. The prediction of the articulatory phonology view is that intervocalic /s/ will be more reduced word-finally than in other positions.

In this respect, the voicing and weakening of /s/ in our Madrid Spanish data may also be connected with the phenomenon of ‘/s/ aspiration’ in a large number of Spanish dialects. In fact, the findings of our study may contribute towards an explanation of some seemingly puzzling facts regarding the context of /s/ aspiration. As already mentioned, in many Spanish varieties, both in Spanish and Latin America, /s/ may be realized as [h] or deleted when syllable-final, either preceding a consonant, as in /éste/ [éhte] ‘this’, /dós tóros/ [dóhtóroh] ‘two bulls’, or before pause, as in /dós/ [dóh] ‘two’. Interestingly, a very common state of affairs is for aspiration to also take place in word-final position before a vowel, /dós animáles/ [dóhanimáleh] ‘two animals’, but not in other intervocalic contexts, /kósa/ [kósa] not **[kóha] ‘thing’ (although there are a few dialects where aspiration is also possible in this environment, see, e.g., Lipski, 1986, 1994; Hualde, 2005, pp. 161–165).

The application of aspiration in, for instance, *más amor* [má.ha.mór] ‘more love’ but not in *masa* [má.sa] ‘dough, mass’ in many Spanish dialects requires an explanation, since in both cases we seem to have the same phonological string /ása/.

Within Generative Phonology, the explanation that has been given involves rule ordering and cyclic application of rules (Harris, 1983, among others). The context for aspiration in the relevant dialects is the coda of the syllable, but reapplication of a syllabification rule places the consonant in syllable-initial position at a later point in the derivation: /más. # a.mór/ → [máh.a.mór] (by aspiration in the coda) → [má.ha.mór] (by resyllabification) ‘more love’. In /mása/ ‘dough, mass’, on the other hand, there is no step in the derivation where /s/ is syllabified in the coda, which prevents it from being aspirated, since the rule targets only coda consonants.

Within an exemplar model, Bybee (2000) provides an explanation that appeals to connections between stored tokens of the same lexical item. She surmises that in Spanish the phonetic context for /s/ aspiration, where the sound change arose, is the preconsonantal one. As noted before, in Madrid Spanish, the dialect that we analyze here, aspiration of /s/ is rare before a vowel and also before pause, but common before certain consonants. Aspiration of word-final prevocalic /s/ would be an extension from the word-final preconsonantal context to other word-final positions by a sort of analogy, with tokens of a word in the context of aspiration affecting the realization of tokens in other contexts. This extension of aspiration from its original preconsonantal context would be due to the fact that /Vs#C/ is more frequent than /Vs#V/ or /Vs##/. To give an example, the frequent occurrence of the word *dos* ‘two’ before a consonant, where it is in the context of lenition, as in *do[h] toros* ‘two bulls’, would affect the mental storage of this word as having an aspirated consonant, so that the variant with [h] could be chosen even before a vowel, as in *do[h] animales* ‘two animals’.

Here we would like to suggest another explanation for the aspiration of /s/ in /Vs#V/ in dialects where intervocalic /s/ is not aspirated in other morphological contexts. Our experimental results show that, even in the absence of aspiration, word-final intervocalic /s/ is also weaker than word-medial or word-initial /s/ (confirming the findings in Torreira and Ernestus, 2012). We can thus offer an alternative explanation that does not require cyclic application of rules or an appeal to analogical influence across phonological contexts: /s/ aspiration is a further development in those contexts where /s/ is already weak. It would be the lack of systematic ‘in-phase’ coordination of /s/ with a following vowel (in Articulatory Phonology terms, Nam et al., 2009) that facilitates the weakening of /s/ and its eventual aspiration. In sound change, /VC#V/ may differ from /VCV/ and /V#CV/ because of a difference in gesture coordination patterns. A transcription of, e.g., *más amor* as [má.sa.mór], with the same sequence of symbols and the same syllable structure as *masa* [má.sa] simply offers an incomplete view of phonetic reality.

Again, we cannot exclude the possibility that the explanation for the weak character of word-final prevocalic /s/ in Spanish may also be of a historical nature. Old Spanish most likely was like Catalan and Portuguese in presenting systematic voicing of word-final /s/ before a vowel in the following word. In fact, Judeo-Spanish, which has preserved the Old Spanish contrast between /s/ and /z/ in word-medial position, has this distribution (Sala, 1971; Hualde and Şaul, 2011). Voicing of intervocalic word-final fricatives is also attested in a few Spanish dialects spoken in Spain that had maintained the voice contrast until the first decades of the 20th century, such as that of Malpartida de Plasencia in Extremadura (Catalán, 1954; Hualde, 1992). Since

all closely related varieties that have preserved the contrasts between /s/ and /z/ in medial position neutralize this contrast in /z/ in word-final position before a vowel, it seems reasonable to assume that that was the state of affairs in Old Spanish as well, before the two phonemes merged. We also note that Ecuadorian Spanish, which, like all other Latin American Spanish dialects, lacks phonemic /z/, has been described as presenting systematic voicing of word-final /s/ when followed by a vowel (Lipski, 1989). Although the traditional understanding is that the phonemic contrast between /s/ and /z/ was neutralized by systematic devoicing of /z/ both word-medially, where /z/ previously contrasted with /s/, and word-finally, where there was no contrast, a more nuanced view may be that, although the two phonemes did merge, with loss of the lexical distribution of /s/ and /z/, the historical devoicing process was not complete, so that noncontrastive voicing of /s/ and a generally weaker articulation in word-final position in modern Spanish continues an older phonetic pattern.

To recapitulate: we have found that intervocalic /s/ is more lenited in Spanish than in Catalan. Although this result is consistent with a principle of contrast preservation operating in Catalan, we have noted that there are alternative, nonfunctional, explanations of the facts, including diachronic ones.

Secondly, we have found that in Spanish intervocalic /s/ is shorter and more prone to voicing when word-final than in other contexts. We attribute this apparent effect of morphological structure to differences in articulatory coordination (which remain to be tested in articulatory studies). Any apparent morphological effects on phonetic realization would be indirect (Torreira and Ernestus, 2012). We have pointed out that this result is also compatible with other synchronic and diachronic aspects of the sound pattern of Spanish and with dialectal developments, and, in fact, helps us understand why aspiration takes place in /Vs#V/ in preference to other intervocalic contexts.

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