Compensatory breathiness in Canary Islands Spanish – an acoustic study of vowels in /s/ weakening contexts

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ABSTRACT

This study investigates the compensatory effects of /s/ aspiration and deletion on the preceding vowel in Canary Islands Spanish. No such effects have been reported to date for this dialect. A phonetic analysis focused on the amount of breathiness in the target vowel, as marked by cepstral peak prominence, shows that the second part of the vowel is significantly breathier than the first when followed by an aspirated coda /s/ or complete coda /s/ elision compared to vowels followed by other segments. Moreover, the shorter the following aspirated /s/, the greater the effect, thus breathiness is modulated by the duration of the following sound. This compensatory effect is possibly phonological and not purely phonetic given that breathiness is also caused by deleted segments and that vowels preceded by an (onset) aspirated /s/ are not affected. Differential effects of /s/ weakening depending on syllable affiliation suggest morphological conditioning.

Keywords: Spanish, /s/ weakening, incomplete neutralisation, phonetics-phonology interface.

1. INTRODUCTION

The weakening of /s/ is perhaps the most well-known phenomenon pertaining to Spanish phonetics and phonology. In its most common form, it consists in the production of a glottal frication [h] in coda position, also referred to as /s/ aspiration [1], although different surface realisations have been reported, including velar fricatives, [ɦ] and [ʔ], among others [2–4]. Furthermore, as an instance of lenition, the process can lead to complete elision in some contexts. Both the degree to which /s/ weakening ensues and the contexts in which it is observed differ from one variety of Spanish to another. Starting with word-internal coda position, word-final prepausal, preconsonantal and prevocalic /s/ can also be affected [5, 6]. Against this background, the dialect of interest in this paper, i.e. Canary Islands Spanish, shows quite extended /s/ weakening with and without voicing, and with optional deletion. Thus, vowels followed by /s/ can surface as [Vs], [Vh], [Vɦ] or [V] in many contexts, both inside words and across word boundaries, before consonants, pauses and vowels standing in a subsequent word. Examples are provided below.

(1) /s/ weakening in Canary Islands Spanish[i]

estás 'you are'
[eh.ˈtas] [eh.ˈtah] [eh.ˈtaɦ] [eh.ˈta]
estás guapa 'you look nice'
[eh.ˈtah.ˈgwa.pa] [eh.ˈtaɦ.ˈgwa.pa] [eh.ˈta.ˈgwa.pa]
estás aquí 'you are here'
[eh.ˈta.sa.ˈki][eh.ˈta.ha.ˈki][eh.ˈta.ɦa.ˈki][eh.ˈta:.ˈki]

Quite importantly, there is a tendency in the literature to focus on categorical distinctions between the above variants [7], although there have also been some works centred around the continuous dimension of coda /s/ weakening [8–10]. In this context, it must be noted that whenever the /s/ is weakened but not deleted completely, its strength and duration may differ from one phonetic environment or speaker to another. The question is whether such differences are systematic and whether they affect the flanking segments. Since coda /s/ is an important grammatical marker in Spanish, corresponding to the plural in nouns, adjectives and pronouns, and to the second person singular in verbs, its weakening may bring important consequences for meaning disambiguation. The complete elision of /s/ can be interpreted as contrast neutralisation. We can think of numerous minimal pairs of words and phrases that sound the same after /s/ deletion, e.g. *estas chicas* 'these girls' vs *esta chica* 'this girl'. However, there have been reports of incomplete neutralisation in some dialects of Spanish. For instance, in Eastern Andalusian and Puerto Rican Spanish vowels followed by weakened /s/ are produced as more open [11–13]. There have also been some reports of vowel duration changes as a result of /s/ weakening [14, 15], which involve both lengthening and shortening. Additionally, it has been claimed that an aspirated vowel is produced in weakening contexts, which may be interpreted as breathy voice, some effects of which have been described recently for Chilean Spanish [16–17]. Nevertheless, research on such incomplete neutralization effects is scarce and based on a variety of dialects, each of which has its own specificity. Many of the existing studies have brought inconclusive or contradictory results. As for the dialect in question, no compensatory effects have been reported in the literature. This study is therefore the first to investigate the influence of /s/ weakening on the preceding vowels in Canary Islands Spanish.

1.1. Rationale for the present study

The immediate inspiration for the present study was an impressionistic exploration of the corpus. The inspection of spectrograms containing /s/ productions in a variety of contexts suggested that preceding vowels may be affected by the turbulence of the following fricative sound in its weakened form. This was followed by personal communication with native speakers who participated in an unpublished perception study consisting in the identification of plural vs singular word forms with variable durations of /s/ aspiration ranging from 115 ms to 0 ms [18]. Some of them claimed that there is a perceptual difference between plural and singular nouns and cutting out the aspiration following the final vowel does not cancel this effect. Thus, given our own observations and speaker intuitions, we set out to investigate the effect of /s/ weakening on the preceding vowels in Canary Islands Spanish. Since glottal fricatives have a tendency to be produced as breathy voice [19], and many of the underlying /s/ are produced as the undoubtedly breathy [ɦ] in the dialect, our expectation was that the preceding vowels are realised as (partially) breathy when followed by a glottal frication.

1.2. Goals and hypotheses

Given the above, the general prediction concerning the dialect is that there is a compensatory effect of breathiness on vowels followed by /s/. Additionally, since the duration of the /s/ is variable, the shorter the following aspirated /s/ ([h/ɦ]), the breathier the preceding vowel. By extension, this implies that full segment deletion should lead to even more breathiness on the vowel because the noise from the consonant is realised partially, if not fully, on the preceding vocoid. Furthermore, there should be a significant difference between the supposedly modal vowels not followed by /s/ and those followed by /s/, and the second half of the vowel should be the one affected given the direction of the exerted influence. The metric used to measure breathiness in this paper is cepstral peak prominence – a measurement considered to be especially robust as a marker of breathiness compared to other metrics [20, 21].[ii] The specific hypotheses are provided below.

H1. CPP(S) is lower (more breathiness) in vowels followed by /s/ compared to vowels followed by other segments (lowest when there is no acoustic cue to the oral gesture of /s/, i.e. /s/ is deleted).

If Hypothesis 1 is supported, there is a compensatory effect of breathiness that comes from the deleted or aspirated segment.

H2. CPP(S) is lower (more breathiness) in the second half of the vowel compared to the first.

If Hypothesis 2 is supported, this confirms the subphonemic and compensatory nature of the change.

H3. CPP(S) is lower (more breathiness) with the decrease in duration of the following aspirated /s/.

If there is a linear trend in the data as per Hypothesis 3, there is evidence for gradient change in the phonation of the vowel preceding the /s/.

In all cases, we do not predict differences in the breathiness effect depending on vowel quality, except that high vowels should be breathier in general (/i u/) [22]. We also look at other parameters associated with sound breathiness, such as intensity [23–25], F0 [26], and the presence of noisy or aperiodic energy in the signal [21, 27], as measured by the harmonics-to-noise ratio (HNR). All of them are expected to be lower in breathy voice.

2. METHODOLOGY

2.1. Corpus and speakers

The corpus gathered for the study consists of digital recordings of semi-structured interviews with 33 native speakers from the north of Gran Canaria (15 females, 18 males) aged 16–79. The recordings were made in February 2016 with the use of a Zoom H4N digital recorder and a Shure SM10a headworn microphone at 44,100 Hz sampling frequency. The corpus contains a total of 105 files containing 3,650 sentences and 96,076 sounds. The sound files were automatically aligned with orthographic transcriptions and pretranscribed phonetically using EasyAlign [28], followed by manual correction. We then extracted all the vowels (N=43,757) together with their acoustic measurements and contextual information. To avoid confusion with intervocalic instances of /s/ realised as [h ɦ], we only included vowels followed by coda /s/ and other consonants or vowels, which gave us a total of 28,134 observations.

2.2. Variables

The extracted variables of interest include target vowel and following sound duration in seconds, as well as smoothed cepstral peak prominence (CPPS) measured at 11 time points in the vowel, following previous literature [29]. Additional measurements include: vowel intensity and standard deviation of intensity, mean harmonics-to-noise ratio, mean pitch, and pitch measured at 11 time points.

2.3. Statistical analysis

Statistical analyses were conducted in R [30] using the packages *lme4* [31] for building models, and *emmeans* [32] for the calculation of simple effects. Two main mixed effects models were built: one on the full database and one on a database excluding segmental deletions. Both models used CPP(S) as a dependent variable. Model 1 used vowel part (part 1, part 2) and following sound type (consonant, vowel, deleted /s/, aspirated /s/) as fixed factors. Model 2 used following sound type and following sound duration in seconds as fixed factors. Both random intercepts and random slopes were included whenever possible in terms of model convergence.

3. RESULTS

3.1 Model 1

The model checking the effects of /s/ weakening on vowels compared to the presence of other following segments was run on a total of 208,968 observations given that the initial number was multiplied by converting the data into long format to include multiple values of CPP(S) as measured at different vowel points. We performed F-testing of fixed effects, obtaining denominator degrees of freedom via Satterthwaite approximation.

The results show a main effect of following sound type (F=2129.92, p<0.001) and a significant interaction between vowel part and following sound type (F=513.05, p<0.001). We then estimated marginal means from the model in order to assess simple effects and take a closer look at the interaction term. As for the pairwise comparisons between the different levels of following sound, all of them resulted significant. Most importantly, following vowels are correlated with a higher value of CPP(S) compared to all other sounds (t=25.17, p<0.001 compared to consonants other than /s/, t=47.78, p<0.001 compared to deleted /s/ and t=70.16, p<0.001 compared to aspirated /s/). Similarly, other consonants are correlated with a higher value of CPP(S), i.e. less breathiness, compared to deleted /s/ (t=37.5, p<0.001) and aspirated /s/ (t=63.75, p<0.001), and deleted /s/ is correlated with a higher value of CPP(S) compared to aspirated /s/ (t=20.47, p<0.001). Fig. 1 illustrates these dependencies. It also shows differences in CPP(S) between the two vowel parts depending on the following sound, with other consonants and vowels raising the CPP(S) of the target vowel in the second part, and all types of /s/, deleted or not, decreasing it, and hence showing a breathiness effect. Additionally, although differences in CPP(S) in the first part of the vowel are significant between all four levels of following sound, we can see that the mean value is especially low in the case of vowels followed by aspirated /s/ (in this case the level of CPP(S) in the first part of the vowel is the same as the level for vowels followed by deleted /s/ in the second part of the vowel, *p*=1).

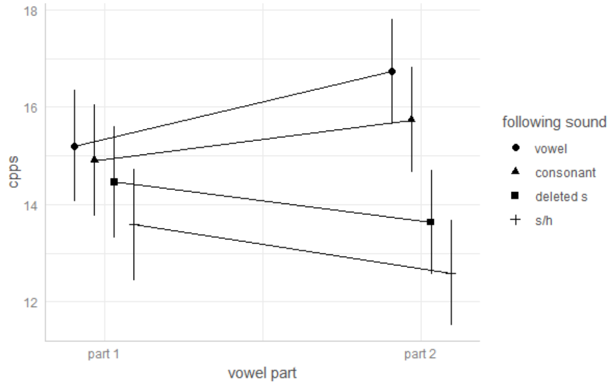

Figure 1: Effects plot for Model 1 showing predicted values of CPP(S) as per vowel part and following sound.

3.2 Model 2

Model 2 (without deleted /s/, i.e. 194,048 observations) shows significant main effects of both following sound duration (F=6.79, p<0.05) and following sound type (F=129.94, p<0.001), and a significant interaction (F=45.97, p<0.001).

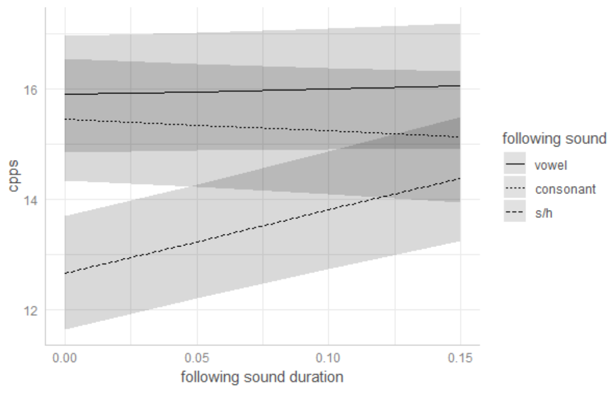

Figure 2: Effects plot for Model 2. Predicted values of CPP(S) as per following sound type and sound duration.

Pairwise comparisons show significant differences in CPP(S) between vowels standing before all types of following sounds when their mean duration is taken into account (see Fig. 2). However, we can see a positive correlation between following sound duration and the CPP(S) of the target vowel only in the case of following aspirated /s/ and no such tendencies when the vowel is followed by other segments, which confirms the compensatory breathiness effect of /s/ weakening (Fig. 2).

3.3 Additional models

The results of additional models with intensity, mean pitch and HNR as dependent variables are shown in a summary table below, where we can see that the expected pattern corresponding to greater breathiness in vowels followed by /s/ obtains in the case of intensity and HNR, while F0 shows the opposite.

model	following sound	*t* statistic
intensity	other vs deleted /s/	59.143***
	other vs aspirated /s/	40.86***
	deleted vs aspirated	-12.38***
HNR	other vs deleted /s/	6.38***
	other vs aspirated /s/	55.51***
	deleted vs aspirated	36.75***
F0	other vs deleted /s/	-23.66***
	other vs aspirated /s/	-14.97***
	deleted vs aspirated	5.95***

Table 1. Pairwise comparisons: additional models.

4. DISCUSSION

The results of the study support Hypotheses 2 and 3. In /s/ weakening contexts, the second part of the vowel is breathier than the first, and the amount of breathiness is modulated by the amount of aspiration. Hypothesis 1 was partially supported in that vowels are breathier when followed by a weakened /s/ compared to other segments but the amount of breathiness is greater before aspirated than deleted /s/, contrary to our predictions. Furthermore, most of the other acoustic parameters associated both with consonant weakening and with breathy voice are in line with the compensatory breathiness interpretation. Thus, our data show that there is a compensatory effect that differentiates vowels followed by coda /s/ from other vocalic segments in Canary Islands Spanish. Since we only looked at following segments, and vowels in the studied dialect of Spanish are equally likely to be found after weakened /s/ as before it, or to flank a weakened /s/ on both sides, it is possible that the observed effect is coarticulatory rather than regressively caused by /s/ weakening. In other words, it may be that neighbouring frication is what affects the vowel and this may take place bidirectionally. To exclude this possibility, we compared vowels followed by /s/ with vowels preceded by /s/, and used following and preceding sonorant consonants as a baseline for comparison. Fig. 3 shows the results of this enquiry. Note that the first part of the vowel is not affected in any case, which is what we would expect given the hypothetical influence of preceding aspiration, and only following aspirated /s/ results in a decrease in CPP(S).

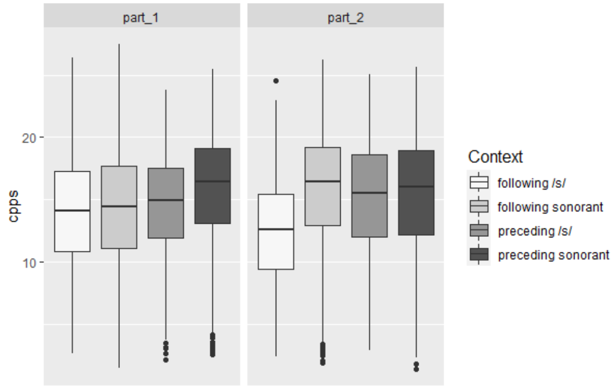

Figure 3: Mean CPP(S) depending on vowel part and /s/ or sonorant position with respect to the target vowel.

We might also expect that vowel duration and not only type of phonation is affected by /s/ weakening [cf. 15-16]. An additional mixed effects model shows that the following sound does affect the duration of the target vowel (F=628.91, p<0.001). Curiously, while /s/ deletion causes vowel lengthening, aspiration is associated with the shortest vowel duration, which suggests a compensatory effect in the former case and coarticulation in the latter.

All in all, the results of the study are interesting from the point of view of the phonetics-phonology interface. On the one hand, we see gradient effects in the form of increasing breathiness of the second half of the vowel with the decreasing duration of following aspiration. Additionally, aspiration leads to lower values of CPP(S) throughout the vowel and not only its second part, as opposed to deletion. On the other hand, /s/ deletion causes both breathiness and lengthening of the target vowel, which is clearly a compensatory change. Both types of weakening are also correlated with lower vowel intensity and HNR, which confirms that such vowels differ from those followed by other sounds, be it consonants or vowels. Furthermore, the effect is only observable when coda /s/ is involved. All of those factors put together suggest that phonology is involved. Vowel breathiness in /s/ contexts has a functional effect: it helps distinguish morphological contrasts, assists in perception when disambiguating meanings and possibly plays a role in learning. It is therefore possible that we are dealing with an ongoing phonologization of contrast, i.e. a transition from gradient breathiness with /s/ aspiration to a categorical change from [Vs] to a breathy vowel [V^h]. Future studies should focus on morphological and prosodic effects, such as disambiguating between coda /s/, onset /s/, onset /x/ realised as [h] and coda /s/ resyllabified as onset.

7. ACKNOWLEDGEMENTS

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[i] All major pronunciations occurring in the dialect are listed, although some are more frequent than others. We ignore other than glottal productions reported e.g. by [3]. Variation in stop weakening typical in this dialect is irrelevant for the present study and is therefore not included.

[ii] Another popular measure, not explored here, i.e. H1 – H2, has proven weak in differentiating the degree of breathiness and can be influenced by nasality [see 21]. It must be noted, however, that at least some speakers use it more reliably than CPP in perception (e.g. in Gujarati, [20]).