Coarticulation between Aspirated-s and Voiceless Stops in Spanish: An Interdialectal Comparison

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1. Introduction

In a large number of Spanish dialects, representing many of the world's Spanish speakers, /s/ is reduced to or deleted entirely in word-internal preconsonantal position (e.g. /este/ → [ehte], *este* 'this'), in word-final preconsonantal position (e.g. /las#toman/ → [lahtoman], *las toman* 'they take them'), and/or in prepausal position (e.g. /komemos/ → [komemo(h)], *comemos* 'we eat'). In those dialects considered the most phonologically innovative (such as the Spanish of Andalusia, Extremadura, Canary Islands, Hispanic Caribbean, Pacific coast of South America), /s/ debuccalization is also found in prevocalic environments word-finally (e.g. /las#alas/ → [lahala], *las alas* 'the wings') and even word-internally, this phenomenon being less common (e.g. /asi/ → [ahi], *así* 'this way'). When considered in detail, the manifestations of aspirated-s can be very different depending on dialectal, phonetic and even sociolinguistic factors. Only in preconsonantal position, for example, different s-apirating dialects behave differently; and, even within each dialect and in preconsonantal position, different manifestations arise as a result of the consonant type following aspirated-s. In this study, I show that aspirated-s before voiceless stops has different phonetic characteristics in Western Andalusian, on one part, and Puerto Rican and Porteño Spanish on the other. While Western Andalusian exhibits consistent postaspiration and shorter or inexistent preaspiration, Puerto Rican and Porteño display consistent preaspiration but no postaspiration. Moreover, Andalusian Spanish voiceless stops in /hC/ clusters show a longer closure than voiceless stops in other conditions, a contrast that does not apply for Porteño and Puerto Rican Spanish. In the discussion, I will argue that a precise timing of some of the gestures involved in the sound sequences studied here is relevant for the sound structure of each dialect. Finally, I will consider an application of the Articulatory Phonology syllabic model to a hypothetical sound change in Western Andalusian Spanish.

2. Correlates of aspirated-s

The most obvious acoustic correlate of debuccalized /s/ is, of course, a period of glottal frication. In Andalusian Spanish, this correlate is typically present in utterance-medial word-final position, such as in the utterance *las alas* [lahala]. However, when we consider multiple phonetic contexts and dialectal differences, the phonetic manifestations of aspirated-s appear as being quite varied and finely detailed. For this reason, in this introduction we will only refer to the context studied here, that is utterance-medial /s/ aspiration before voiceless stops.

In a perception study on Miami Cuban Spanish carried out with natural stimuli, Hammond (1978) found that speakers were unable to detect utterance-final /s/, while they consistently distinguished minimal pairs such as *costa* ~ *cota* (the word *costa* being always pronounced without a full sibilant). It follows from this that, when confronted with *las costas* 'the coasts', speakers relied on cues in the medial part of the utterance in order to distinguish it from *la costa*, since utterance-final /s/ was categorically lost. After analyzing the acoustic differences among the stimuli used in the experiment, it was found that the vowel preceding aspirated /s/ (e.g. /a/ in *gasto*) was considerably longer than vowels in open syllables (e.g. *gato*). This effect was recently replicated for Puerto Rican Spanish in a study sharing the same design and test-words as Hammond (1978) (Figueroa, 2000). Gerfen (2002) also found that for words sharing this pattern Eastern Andalusian speakers also tended to produce

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longer vowels preceding weakened /s/. However, this study explicitly mentioned that in order for this effect to be significant, vowel duration needed to include the period of aspiration corresponding to weakened /s/. If this period was not counted as being part of the vowel, the latter was actually slightly shorter than vowels in open syllables, as would have been expected since vowels in tautosyllabic VC sequences usually tend to be shorter than open-syllable nuclei. The motivation for including the aspiration period within the vowel was that, in many cases, they could not be clearly delimitated from each other during segmentation, and also that in other cases speakers did not produce voiceless aspiration, but rather different degrees of breathiness towards the end of the vowel. Since neither Hammond (1978) nor Figueroa (2000) explicitly mentioned this issue in their studies, one can wonder whether their stimuli were totally devoid of any aspiration or breathiness, as they suggest, or whether some aspiration or breathy voicing was actually present but was not considered in their segmentation.

Another widely-described correlate of /s/ debuccalization in this and other phonetic contexts is the opening of mid and low vowels in Eastern Andalusian varieties (EAS) (Navarro Tomás, 1939; Alonso et al., 1950; Alvar, 1955; Salvador, 1977)). In these dialects, the vowels /a, e, o/ are said to be open or lax when followed by weakened /s/ (whether /s/ aspirates or deletes). Moreover, this opening seems to extend to preceding vowels in the prosodic word, in a typical example of vowel harmony (e.g. [loBo] , 'wolf' vs. [lOBO(h)], 'wolves'). Even though these two features have been traditionally taken for granted in the phonological literature, it should be admitted that little instrumental evidence supports them so far. In reexamining experimental data from Martínez Melgar (1986), Maza (1999) argues that vowel harmony is not consistent when examined in detail (it is not clear, for example, what the domain of the phenomenon is), and that vowel opening is characteristic of both stressed syllables and of vowels preceding weakened-s, without any causal relationship between the two phenomena. Hualde and Sanders (1995) posit that EAS might not have reduced its number of mid vowels in its evolution from Romance as Standard Castilian did, and find support for this case in that rural EAS speakers display higher /e/ and /o/ than speakers of the 5-vowel standard dialect. The data presented by Martínez Melgar (1986) further complicate the picture. In spite of considerable variability in her data, this author claims that open and close vowels do not differ as much in word-final position as in penultimate stressed syllables. At the present time we will conclude that, even though the situation does not seem as clear as depicted in traditional accounts, it seems reasonable to assume that speakers of Eastern Andalusian Spanish do somehow associate the occurrence of lax vowels with weakened /s/. As for other dialects, we will note that Hammond (1978) and Rodríguez Cadena (2003) also report data from Cuban where vowels undergo F1 raising in the context discussed, even though both studies found little consistency in the effect.

Finally, in the study on Eastern Andalusian Spanish cited above, Gerfen (2002) identified stop closure duration as the most robust correlate of /s/ weakening in words of the type [CVh.CV] where the second consonant was a voiceless stop. It was found in this study that the closure of voiceless stops preceded by aspirated /s/ was significantly longer than stop closures in V.CV contexts.

3. The study

Three groups of three speakers of three different Spanish dialects – Western Andalusian, Porteño and Puerto Rican– read a list of sentences carrying the test words and distractors, the carrier sentence being *Digo X para mí* 'I say X for myself'. The author, a native speaker of Western Andalusian Spanish, did not participate in the recordings. The test words were selected in a balanced way by considering the factors below. All were paroxytones and ended in a low or mid back vowel. In a small number of cases nonce words were used in order to satisfy certain combinations of factors (a list of the test words can be found in the Appendix):

1. STOP TYPE: /p/ vs. /t/ vs. /k/ (e.g. /pa**p**a/ vs. /pa**t**a/ vs. /pa**k**a/)
2. CODA TYPE: 0 vs. /l/ vs. /s/ (e.g. /kako/ vs. /ka**l**ko/ vs. /ka**s**ko/)
3. VOWEL TYPE: /a/ vs. /i/ (e.g. /t**a**po /vs. /t**i**po/)

The test word counts were: 3 different words x 3 stops x 3 preceding consonants x 2 preceding vowels for a total of 54 test words. With 3 repetitions for each of the 9 speakers, the total number of

tokens in the database was 1458. The readings were carried out in a quiet room and recorded using a Shure SM10A head-mounted microphone, an M-Audio 410 Firewire audio interface/preamplifier and a Macintosh PowerBook laptop computer. The speakers were informed that they were taking part in a study of how people from different regions speak and that they should try to speak in a natural and relaxed fashion, as if they were at home with friends. These instructions were aimed at mitigating the chances that standard orthography might induce the speakers to pronounce a full sibilant where the experimental design required weakened /s/. Indeed, the author checked that /s/ was weakened as required by the study, and discarded a minimal number of full sibilant pronunciations[1]. Once the data were collected, each token was extracted and the following measurements were manually taken using Praat software (Boersma and Weenink, 2005):

1. VOT: Voice Onset Time for the target voiceless stops.
2. STOP CLOSURE: Duration of the stop closure for the target voiceless stops.
3. L / PREASPIRATION: Duration of the consonants preceding the target voiceless stops: [h l]. For tokens lacking this consonant (e.g. [kapa]), the value for this measurement was 0 ms.
4. V: Duration of the vowels /a/ and /i/ preceding the target voiceless stops.

Following standard instrumental procedures for measuring VOT, waveforms were used rather than spectrograms, the former allowing for a better resolution. After browsing through a good number of tokens, we finally decided to mark the ending point of VOT at the downward zero-crossing before a whole first cycle could be perceived in the signal. Even though this method cannot be considered entirely faithful to the events in the speaker's glottis, the signal being the result of overlapping supraglottal and glottal gestures, it appeared to be a consistent way of measuring VOT in the absence of articulatory data. Another issue concerning our VOT measurements is that they include the stop release and a period of supraglottal frication besides postaspiration, even if our hypothesis focuses exclusively on postaspiration. Because these three events overlap in the signal (Stevens, 1998, p.456), the whole sequence of events at the release of the stop was preferred over strict postaspiration as a more reliable measurement. All other things being equal, we assumed that postaspirated stops should display a longer VOT than unaspirated stops. However, it could be argued that this difference could in fact be a difference in supraglottal frication, and not in postaspiration. We must say that, during segmentation, a considerable stretch of postaspiration was clearly identified in most tokens where it was expected to occur, even though we decided not to delimit it from supraglottal frication for the sake of consistency. The token in Fig. 1 illustrates the presence of postaspiration within the VOT bounds.

Another potential segmentation issue concerned the beginning and ending points of aspirated /s/ in the tokens pronounced by the Andalusian group, as was observed above in our review of Hammond (1978), Figueroa (2000) and Gerfen (2002). Here we decided to mark the beginning point where F2 showed a clear decrease in energy, whether the following aspiration period displayed some sort of breathy voicing or plain aspiration. As for the ending point, a problem was raised by spurious energy spots that occasionally appeared during –and well into– the stop closure. Since comparable spots appeared in the medial closure of words without aspirated /s/ such as /pata/, they were considered as perturbations not attributable to glottal frication. For this reason, the ending point was marked with reference to high frequencies (4000-5000 Hz), where these spots were not perceived. The complete segmentation procedure is illustrated in Fig. 1.

[1] An anonymous reviewer wonders how tokens where /s/ is not weakened would compare to the data used in this study in terms of the acoustic correlates analyzed. Unfortunately, our data do not allow us to answer this question since the number of excluded items displaying a full sibilant was not sufficient to perform a statistical analysis.

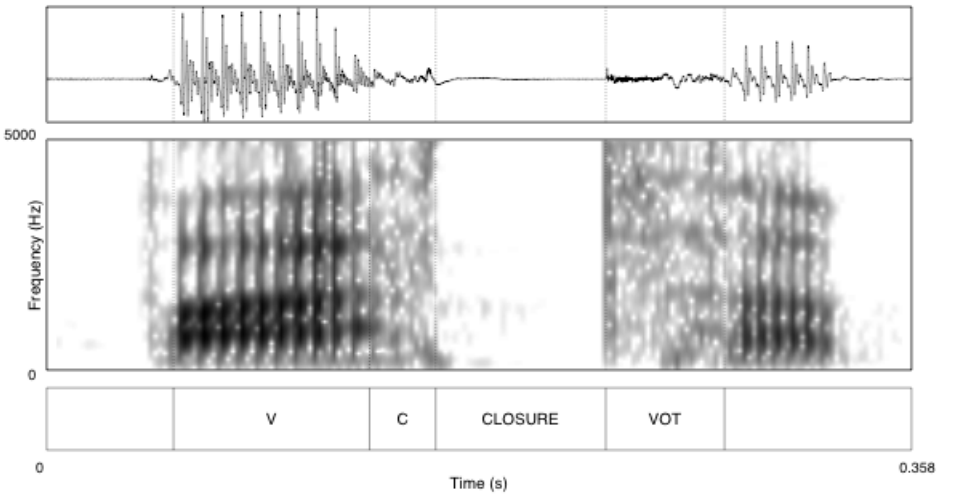

Figure 1 Segmentation procedure as applied to the test word *pasta* [pahta] uttered by an Andalusian speaker.

4. Results

Fig. 2 illustrates VOT values for the three dialects under CODA TYPE and STOP TYPE conditions. In the Western Andalusian data, there is an obvious difference between stops preceded by aspirated-s (/s/ in the graphs) and other stops. A look at the Porteño and Puerto Rican data reveals that no trend seems to apply for these dialects. A series of repeated-measures ANOVAs was carried out for each STOP TYPE in each dialect with VOT as the dependent variable, CODA TYPE a within-subjects factor and SPEAKER a between-subjects factor. These tests revealed that for each speaker, all Andalusian stops preceded by /s/ were statistically different from stops under other CODA TYPE conditions [$F(2,157) = 165.85$, $p < 0.001$ for /p/; $F(2,157) = 168.37$, $p < 0.001$ for /t/; $F(2,157) = 5.60$, $p < 0.01$ for /k/]. As for the other two dialects, effects were found for Porteño stops /t/ [$F(2,157) = 27.48$, $p < 0.001$] and /k/ [$F(2,51) = 123.62$, $p < 0.001$]; an effect was also found for Puerto Rican stop /k/ [$F(2,157) = 6.58$, $p < 0.01$]. A look at Fig. 2 shows that in these cases VOT values were slightly higher for stops preceded by aspiration than for stops in other contexts.

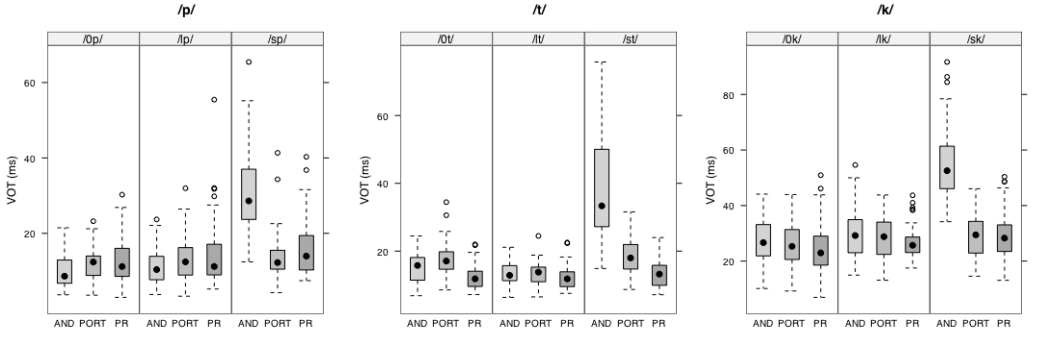

Figure 2 VOT values in ms. for each STOP TYPE divided by CODA TYPE and DIALECT.

The second main variable observed was STOP CLOSURE, in order to check whether the two American dialects would also exhibit a contrast in duration depending on CODA TYPE. In Andalusian, closure duration was found to be longer when preceded by aspirated /s/ than under the other two coda conditions ([$F(2,157) = 30.39$, $p < 0.001$ for /p/; $F(2,157) = 28.11$, $p < 0.001$ for /t/; $F(2,157) = 25.92$, $p < 0.001$ for /k/]). Similar repeated-measures ANOVAs with CODA TYPE as

within-subjects factor and SPEAKER as between-subjects factor were also done for each STOP TYPE in Porteño and Puerto Rican. No significant effect was found for any of the two dialects. The boxplots in Fig. 3 illustrates STOP CLOSURE durations for the three dialects.

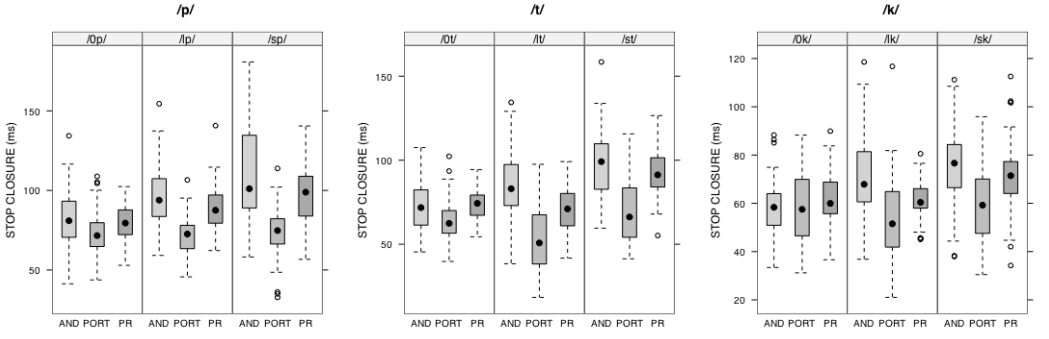

Figure 3 STOP CLOSURE duration values in ms. for each STOP TYPE divided by CODA TYPE and DIALECT.

The third variable observed was the length of the consonant preceding the stop closure in words displaying aspirated-s, that is the duration of the preaspiration period. A repeated-measures ANOVA with DIALECT as within-subjects factor and STOP TYPE as a between-subjects factor revealed that PREASPIRATION was significantly different depending on DIALECT [$F(2,481) = 159.08$, $p < 0.001$]. Fig. 4. illustrates PREASPIRATION values divided by STOP TYPE and DIALECT. It can be seen that, for all stop consonants, Western Andalusian displays shorter (sometimes inexistent) preaspiration in comparison with Porteño and Puerto Rican Spanish.

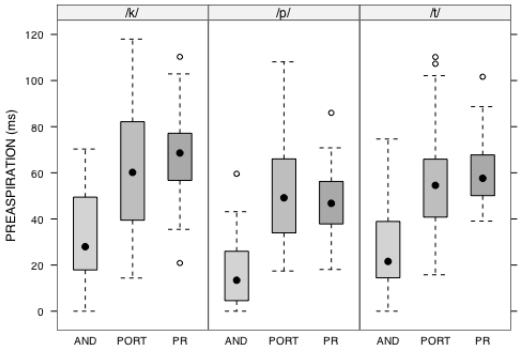

Figure 4 PREASPIRATION duration values in ms. for the three dialects, divided by STOP TYPE and DIALECT

In summary, a VOT contrast was found in Western Andalusian between voiceless stops preceded by aspirated-s and stops in the other two CODA TYPE conditions. Even though effects were found for Porteño and Puerto Rican Spanish, the medians and distributions shown in Fig. 2 suggest that these effects are less important than the ones found for Western Andalusian. Regarding STOP CLOSURE duration, statistical differences were found for Andalusian stops depending on CODA TYPE (/sC/ > /lC/ > /0C/), but no such differences were found for any of the two other dialects. Finally, PREASPIRATION was found to be statistically shorter in Western Andalusian than in the other two dialects.

5. Discussion

The findings of our study suggest that there are systematic dialectal differences in timing for the gestures involved in aspirated-s plus voiceless stop sequences. For the time being, we will assume that

the gestures used for these sequences are the same for the dialects studied here (it might be that Porteño Spanish has some sort of constriction involving the tongue body before the stop closure in words like *casta,* while no such constriction is present in Western Andalusian). In the absence of any articulatory data, therefore, we will focus on the gestures that are shared by all three dialects. Fig. 5 plots time values of four acoustic cues with respect to the start of V1 in the utterances of one speaker per dialect. In this discussion, I will consider these cues as indirect correlates of vocal tract gestures. PREASPIRATION START and VOT END will be correlates of a glottal opening gesture, while CLOSURE START and CLOSURE END are considered correlates of a supraglottal constriction gesture with different place of articulation depending on the stop consonant concerned.

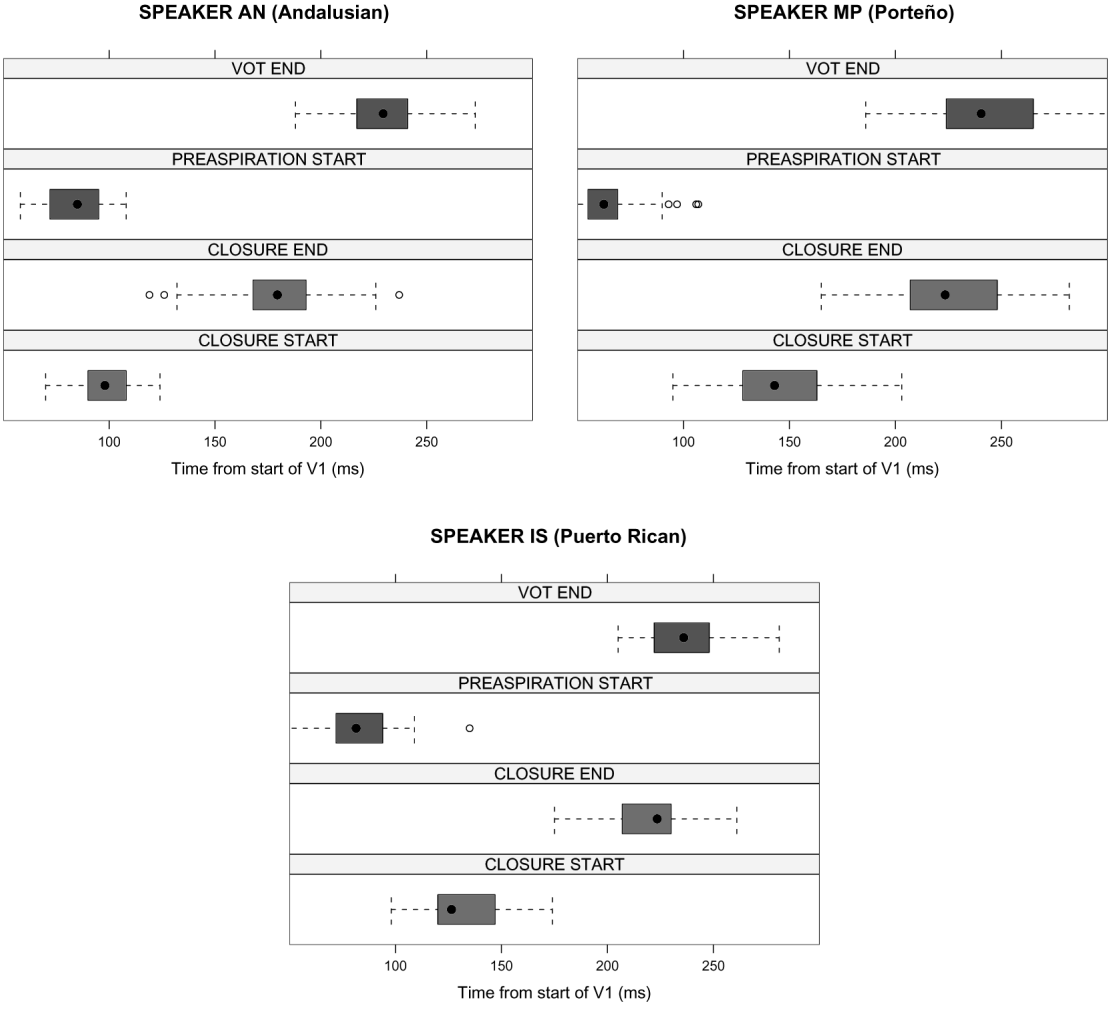

Figure 5 VOT END, PREASPIRATION START, CLOSURE END and CLOSURE START values (ms) with reference to the start of V1.

It can be seen in this figure that Andalusian speaker AN produces earlier stop closures in comparison with the other two speakers. This results in a shorter preaspiration period, and, on the other side of the closure, in a longer postaspiration period. Now we need to consider the fact that in Andalusian, stop closures were longer in /sC/ than in /lC/ and /0C/ sequences, and also that they were longer than in the two other dialects. We will interpret these effects within the Articulatory Phonology framework (Browman and Goldstein, 1989) model of the syllable. This framework posits that gestures involved in syllable onsets tend to couple into an in-phase relationship, while gestures in coda position

are left out of phase with respect to surrounding gestures. This means that at syllable onsets, gestures will tend to have a simultaneous start, while more variability in intergestural timing will be found at syllable codas. Here, we will hypothesize that postaspiration in Western Andalusian voiceless stops preceded by aspirated-s is no more than the acoustic consequence of a gestural reorganization at the onset of the syllable, that is at the start of the stop closure. More particularly, it is possible that the start of the glottal opening and the start of the supraglottal closure gestures are tending towards an in-phase coupling. However, experimental results should confirm this hypothesis more appropriately than the data collected here can allow. For the time being, we propose the following gestural scores, one for Western Andalusian and the other one for Puerto Rican and Porteño Spanish (Fig. 6):

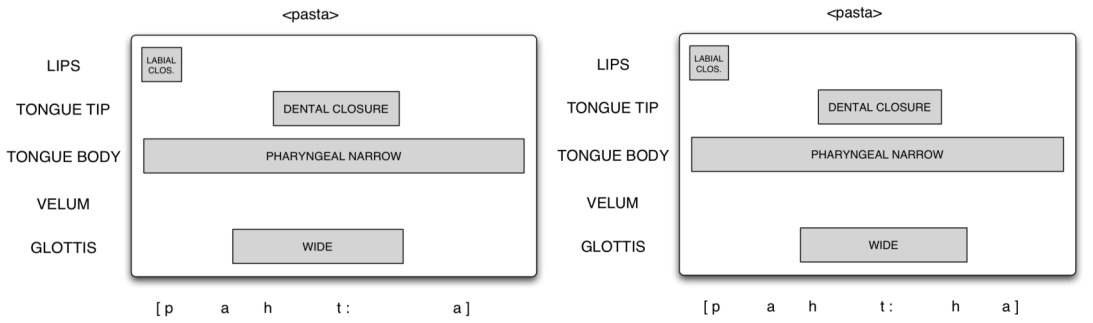

Figure 6 Gestural scores for the word pasta in Western Andalusian (left) and Porteño and Puerto Rican Spanish (right).

Finally, the possibility of a sound change in Western Andalusian Spanish also needs to be considered. It is known that other languages like Pali underwent this same process (*asti* Sanskrit vs. *athi* in Pali) (Vaux, 1998). Should the syllable-driven hypothesis be verified in future research, we might predict the rise of a series of aspirated stops in Western Andalusian Spanish.

6. Conclusion

In this study, it has been shown that the acoustic cues of aspirated-s before voiceless stops are different between Western Andalusian Spanish on the one hand, and Puerto Rican and Porteño Spanish on the other. In minimal pairs such as *pata* vs. *pasta*, Western Andalusian Spanish displays a contrast in stop closure duration, postaspiration and preaspiration. When compared to the two other dialects, Western Andalusian voiceless stops preceded by aspirated-s have a longer VOT (postaspiration), shorter preaspiration and longer stop closure. Porteño and Puerto Rican Spanish, on the other hand, do not seem to display such a clear phonetic contrast in VOT between voiceless stops preceded by aspirated-s and voiceless stops in other contexts. In the discussion I have favored a gestural analysis to account for this dialectal difference and also for a possible ongoing sound change in Western Andalusian Spanish. More particularly, I have hypothesized that the gestural reorganization displayed by the Andalusian data might be driven by the more stable phase relationship characteristic of gestures at syllable onsets. If this is the case, it would be interesting to examine clusters formed by debuccalized /s/ and other consonants (e.g. voiced and stops, /n/), and see if they also conform to the gestural reorganization postulated here for voiceless stops. Perhaps future work will elucidate this issue.

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