

An articulatory view of historical /s/-aspiration in Spanish

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The historical process of s-aspiration is common to many dialects of Spanish. This phonological process can be characterized as assimilation or loss of syllable-final /s/. The exact origins of aspiration are controversial and a variety of explanations have been proposed to account for the conditions that triggered the change. In this paper, a dialect comparison approach is taken in order to provide some experimental phonetic data on the phenomenon. It is suggested here that the origin of aspiration can perhaps be found in the evolution of Middle Spanish sibilants, which gave rise to a difference in the articulatory characteristics of /s/ in two dialects: Castilian, with an apical /s/, and Andalusian, with a laminal /s/. It is further suggested that it is precisely the laminal nature of Andalusian /s/ that might have given rise to aspiration, through gestural reduction, in this dialect but not in Castilian. In order to investigate this hypothesis, articulatory data were obtained from the aspirating dialect – Andalusian – and the non-aspirating dialect – Castilian – through the use of an electromagnetic tracking device (EMMA). The experiments confirmed the presence of a lamino-predorsal /s/ in Andalusian and an apical one in Castilian. Further, they revealed substantial differences in articulatory and dynamic characteristics of the two /s/s, which are taken as support for the gestural reduction hypothesis.*

0. Introduction

The purpose of this paper is to investigate some phonetic factors related to the historical development of aspiration of syllable-final /s/ in certain dialects of Spanish. Following the assumption that sound change takes place first at the phonetic level and that synchronic dialect comparison is a useful tool in explaining diachronic processes, it is suggested here that the origin of /s/-aspiration can be found in the evolution of sibilants in Middle Spanish and, more precisely, in the consequences that this evolution had for the articulatory characteristics of Spanish /s/ across dialects. Articulatory data will be presented from two different dialects of the language: Andalusian, with /s/-aspiration, and Castilian, without /s/-aspiration. A comparison of the data supports the notion that the origin of /s/-aspiration in Andalusian might be related to the presence of a lamino-predorsal /s/ in this dialect. It is also claimed here that the subsequent evolution of syllable-final /s/ in Andalusian can be attributed to a process of weakening or reduction of the gestural magnitude associated with this consonant.

1. *Aspiration in Spanish. Description and origins*

Aspiration of syllable-final /s/ is a common phenomenon in many dialects of Spanish, both in Spain and in the Americas. In Spain, although it is also observed elsewhere, it is most prominent in Andalusian, the dialect spoken in the southern part of the peninsula. Within Andalusian, two main dialect subareas are often recognized, among other things, on the basis of the effects of the aspiration rule: the eastern variety, where aspiration of word-final /s/ has given rise to new vowel categories and a redistribution of the vowel space (Salvador 1977), and the western variety, where the effects of the rule are context dependent and the vowel system is not affected (Alvar 1955).

The realization of the aspiration rule in the western variety of Andalusian has occasionally been described as a simple substitution of [h] for syllable-final /s/ (Goldsmith 1981), as in /espéra/ → [ehpéra] 'wait'. More detailed accounts (Zamora Vicente, 1969; Carbonero Cano, 1982) have remarked a wide range of variation in the phonetic outcome of the rule. In absolute final position /s/ is generally lost: /lúnes/ → [lúne] 'Monday'; in word-final position preceding a vowel, [h] is commonly heard: /lúnes aburrido/ → [lúneh aβuri^ho] 'boring Monday'; in syllable-final position (word-internal or final) preceding a consonant, the underlying /s/ assimilates in different ways to the consonant: complete assimilation (gemination) is often heard in contact with nasals, laterals and other fricatives, as in /ásma/ → [ámma] 'asthma', /eslábo/ → [elláβo] 'slavic' and /esfwrso/ → [effwérso] 'effort', respectively; phonetic pre- or post-aspiration (and occasionally gemination) in contact with voiceless stops, as in /estádo/ → [e^htá^ho] or [e^htá^ho] 'state'; in front of voiced stops aspiration interacts with spirantization (a process by which voiced stops surface as continuants in certain environments) and voiced fricatives are often the result: /rjésgo/ → [rjéγo] 'risk'. As can be seen, the effects of aspiration of implosive /s/ in western Andalusian are in reality far more complicated than it has sometimes been reported. Work on other dialects that undergo the historical phenomenon of aspiration (Marrero 1990) suggests that the effect of the rule is not the simple /s/ → [h] change in those dialects, either, which could be an indication of the general inadequacy of the common representation of the rule for all dialects.

The historical origins of aspiration are controversial both in terms of its date of appearance and the conditions that caused it. Estimated dates of appearance of the phenomenon vary considerably. The most conservative place it as a relatively new phenomenon, non-existent before the 17th or the 18th centuries (e.g., Torreblanca 1989), while the most adventurous claim evidence of aspiration even in late Latin inscriptions (Frago 1983). The most widely acknowledged estimates

(Lapesa 1981) place it, as expected, somewhere in between. It is probably safe to assume that aspiration of /s/ was not considered an unusual phenomenon in Andalusia, particularly in the Seville area, toward the first half of the 16th century. As for the causes of the change (not just in Andalusian, but also in related Romance languages such as French and Occitan), several hypotheses have been advanced (see Marrero 1990 for a more detailed account). Grammont (1946) suggests the possibility that the previous vowel caused the opening of the constriction for /s/. Martinet (1955) mentions a general tendency in languages toward open syllables. Straka (1964) raises the possibility that the weakening of the tongue movement might be associated with the presence of a predorsal /s/ in syllable-final position. Finally, Méndez Dosuna (1987) mentions syllabic principles as the possible cause for /s/-aspiration.

2. *An articulatory perspective on historical sound change*

Explanation of historical sound change has for some time been constrained and biased by the theoretical assumptions about the nature of phonology implicit in the generative model (Chomsky & Halle 1968; King 1969). By concentrating on phonological patterns and distinctiveness, theorists assumed that sound change operates at the same formal level as synchronic contrast, i.e. the phonemic level. Therefore, explaining a diachronic change consists in developing the rules that can account for such a change. The disadvantages of such an approach to diachronic linguistics have been pointed out extensively in recent years (Harris-Northall 1990; Faber 1992). It has also been pointed out that sound change is hardly ever categorical, as a rule-based approach would imply, but rather the effects of a particular mutation in a language's sound system are most generally gradual and progressive (Labov *et al.* 1972). Change spreads through the system both syntagmatically and paradigmatically. Such a vision of sound change suggests that change takes place, at least in its earlier stages, at the phonetic level (Ohala 1974; Faber 1992) and, most likely, within a restricted lexical group. It also implies that several stages of a sound change could be present at any given time within a particular language community. It should, therefore, be possible to obtain important information regarding sound change from comparative phonetic studies across dialects of a given language (Labov 1974; Terrell 1981) or even by looking at similar processes in different languages.

Phonetic approaches to sound change have suggested the possibility that certain diachronic changes are conditioned by acoustic/auditory similarity (Ohala 1981). In short, a sound might be substituted for

another because the two share some acoustic properties that, under certain conditions, might make them hard for the listener to distinguish. Ohala (1974) explains the Norwegian $s \rightarrow \text{ʃ}$ change in these terms. The well-known change from $/s/ \rightarrow /f/$ in English, as in Middle English *rough* [roux] \rightarrow Modern English [raʃ], has been ascribed to the acoustic similarities between labials and velars (Jonasson 1971). An explanation in these terms for the aspiration of $/s/$ in Spanish is proposed in Widdison (1991, 1992, this issue), which suggests that, under certain speech conditions such as fast rate, unstressed environment or syllable coda position, the [h]-like portion of the transition between a vowel and an $/s/$ might have been identified as the $/s/$ itself.

Some important theoretical and practical shortcomings of an acoustic similarity approach to sound change have been pointed out recently by Mowrey & Pagliuca (1987, this issue) and Pagliuca (1982), who advocate, instead, a theory of sound change based on articulatory principles. They suggest the possibility that most if not all sound changes are articulatorily based and can be viewed as weakening processes, where articulatory gestures overlap and blend over time and are reduced in their magnitude. However, they do not provide much articulatory evidence for the kind of processes they propose (but see Mowrey & Pagliuca this issue for some relevant data). It is logical to assume, however, that diachronic and synchronic processes are governed by the same basic phonetic/phonological principles. Thus, processes that are part of a language's synchronic phonology are likely to be the same as or similar to certain diachronic processes in a different language: one could speculate that the present variation in the outcome of $/s/$ aspiration in Andalusian is likely to be similar to the situation in French in the 12th or 13th century (Straka 1964).

Given that similarity, we can conclude that a theory of phonology that attempts to explain synchronic phenomena in terms of articulatory organization ought to be able to offer equally valuable insights in the case of diachronic processes. The theory of articulatory phonology (Browman & Goldstein, 1989, 1992) does precisely this in that it regards articulatory gestures as the basic units of phonological organization. Experimental articulatory data support the notion that at least some common phonological processes can indeed be explained in terms of overlap and blending of gestures or in terms of reduction of gestural magnitude. Browman and Goldstein (1991) present an explanation (from Pagliuca 1982) of the above mentioned $/x/$ to $/f/$ change in English in terms that are in accordance with the general linguistic and evolutionary principles and predictions stated in Mowrey & Pagliuca (1987, this issue).

In this paper, an attempt will be made to explore, from an articulatory

perspective, some possible factors behind aspiration of $/s/$ in Andalusian. For that purpose, we will compare experimental data from two dialects of Spanish: western Andalusian (from now on referred to simply as Andalusian), an aspirating dialect described above, and Castilian, a non-aspirating dialect. First, however, we will take a look at the historical developments that may have led to the emergence of aspiration in one dialect but not in the other.

3. The possible articulatory basis of aspiration. Comparison of aspirating and non-aspirating dialects

The two factors that characteristically differentiate Castilian from Andalusian are, on the one hand, the number and nature of voiceless fricatives and, on the other hand, the presence or absence of aspiration of implosive $/s/$. Castilian has a contrast between voiceless fricatives at the dento-alveolar point of articulation: $/s/$, usually described as apicoalveolar, and $/θ/$, a laminodental or interdental non-strident fricative, while Andalusian has only one category in that region, which we will assume to be underlyingly $/s/$, and that can be realized, in broad terms, either as $[θ]$ or as $[s]$, depending on the effects of aspiration described above, this de Soto 1981). Because of the effects of aspiration described above, this Andalusian fricative only surfaces as $[s]/[θ]$ in syllable initial position, whereas the two Castilian segments $/θ/$ and $/s/$ can occur either in syllable-initial or syllable-final positions.

While in Castilian the distinction between $/θ/$ and $/s/$ is stable, the $[s]/[θ]$ variation in Andalusian is not. Traditionally Andalusian has been thought to realize its dentoalveolar fricative either as $[θ]$ or as $[s]$, but it is likely that such a view is largely influenced by the existing categories in Castilian (the prestige dialect in Andalusia) and by the characteristics of the spelling system, which, following the Castilian model, has different symbols for $/θ/$ and for $/s/$: 'z' and 'c' for $/θ/$, but 's' for $/s/$. In reality, however, the situation is more complex. Accounts of the articulatory nature of $/s/$ in Andalusian (Zamora Vicente 1969; Narbona Jiménez & Morillo-Velarde 1987) reveal that there is much variation in its phonetic realization: basically it can be realized as a laminal, coronal or predorsal fricative with a constriction location situated anywhere between the teeth and the alveolar ridge.

The historical origin of the differences between the two dialects and of the variation in Andalusian can be found in the so-called 'sibilant turmoil' of Middle Spanish (approximately from mid 15th to mid 17th century) (Kiddle 1977; Lapesa 1981). Medieval Spanish presented a rather large set of fricatives and affricates in the dentoalveolar and

alveolopalatal region. These consonants arose from a large number of palatalization processes in Protoromance (Lapesa 1981; Väänänen 1963), many of which are common to other varieties of Western Romance. Toward the end of the 13th century, Spanish had the following set of sibilants: the dental affricates /tʃ/ and /dʒ/, the alveolar fricatives /s/ and /z/, the alveolopalatal fricatives /ʃ/ and /ʒ/, and /f/, a voiceless alveolopalatal affricate -- as well as [ʃ], an affricated variety of /ʒ/ that most likely occurred in initial position.

A simplification of this system took place in all dialects of the language, but the outcome was not the same in the North (Castile) as in the South (Andalusia) (Alarcos LLorach 1961; Alonso 1969). In all areas the occlusive element of the dental affricates /tʃ/ and /dʒ/ was lost, so that /tʃ/ became /s/ and /dʒ/ became /z/. Further, the voicing distinctions were generally lost, so that /s/ and /z/ merged into /s/, /s/ and /z/ merged into /s/, and /ʃ/ and /ʒ/ merged into /ʃ/. In the northern dialects of the language (Castilian) the three-way contrast /s, s, ʃ/ was maintained by polarizing the distinctions, thus making them more salient: dental /s/ was fronted to /θ/, alveolar /s/ was retracted slightly to become an apicoalveolar /s/, and alveolopalatal /ʃ/ was pushed backwards in the mouth to become velar /x/. In the south (Andalusian) the distinction between /s/ and /s/ was lost and the two merged into a single segment that, as we saw, varies from laminodental to predorsoalveolar, while /ʃ/ presumably became /x/ as in Castilian before being weakened further to /h/.

The rearrangement of the fricative/affricate system of the language can be seen as responsible for the articulatory differences in the realization of /s/ in the two dialects (Zamora Vicente 1969). In Castilian, because of the polarization between the dental and alveolar points of articulation, the tip of the tongue was retracted to acquire the characteristic apical -- bordering on retroflex -- position of modern /s/ (Joos 1952). In Andalusian, on the other hand, the blending of the fronted laminodental position of the tongue for /s/ with the alveolar constriction location of /s/ resulted most likely in a constriction location in between the two, with a characteristic laminar tongue shape but a variety of constriction locations.

Other changes aside, the different solutions to the rearrangement of sibilants represented a clear reduction in the homogeneity of the language. As we mentioned above, the treatment of dentoalveolar sibilants is one of the characteristics that distinguish Castilian from Andalusian (and the American dialects). It is conceivable that the other distinguishing characteristic, aspiration of syllable-final /s/, is somehow related to the development of sibilants, since it has not been proven that aspiration existed before the sibilant merger and it seems to have appeared at a similar time or shortly thereafter. That hypothesis might have been implicit in early accounts of the articulatory characteristics of

/s/ in Andalusian (as a means to investigate the possible evolution of the same process in Old French) in work by Chlumsky (1929), Malmberg (1950) and Straka (1964). Even though none of the mentioned accounts actually link the origin of /s/ aspiration to the rearrangement of sibilants, some do see a connection between the existence of a predorso-dentoalveolar realization of /s/ and aspiration, either as its direct cause (Malmberg 1950) or as the appropriate kind of environment for weakening processes to take place (Straka 1964).

In any case, whether directly caused by the merging of dentoalveolar fricatives or not, it seems that the origin of aspiration might have to do with a weakening of the tongue-tip gesture related to the characteristics of the tongue during the production of /s/.² It is, of course, not possible to look at how weakening affects syllable-final /s/ in Andalusian, since, in that position, phonetic [s] does not occur. If, however, the weakening process has to do with the predorso-dentoalveolar nature of /s/, then it should be possible to obtain some information concerning the relationship between that type of consonant and weakening of the tongue-tip gestures by looking at the /s/ that does occur in the dialect, that is, in syllable-initial position. For that purpose, we shall try to compare the articulatory characteristics of the predorso-dentoalveolar /s/ of Andalusian and its apicoalveolar counterpart in Castilian. Experimental articulatory data for /s/ in the two languages and an examination of some of the results are reported in the next section.

4. Experimental data. Methods and results

The data reported here were collected in two separate experiments: one with a native speaker of Castilian from the Barcelona region and one with a native speaker of Andalusian from Seville. Tongue movement data for the two subjects were collected using an electromagnetic midsagittal articulometer -- EMMA or magnetometer -- (Perkell *et al.* 1992). The magnetometer consists of two main parts: a) a head mount with three magnetic transmitters that generate a magnetic field covering the entire area of articulation of the subject; b) a set of small transducer coils that can be attached to numerous places in the midsagittal plane of the subject's vocal tract. As the articulators, such as the tongue, move inside the vocal tract during speech, the transducer coils create distortions in the magnetic field which result in a set of voltages. The voltages thus created can be converted, through software manipulation, to distance. In the present experiments, coils were placed on the upper and lower lips, tongue tip (TT), tongue blade or lamina (TBL) and tongue body or dorsum (TB), as well as at the lower incisors for an estimate of jaw

movement and the bridge of the nose and upper incisors for head movement correction.

The experimental designs included stops and fricatives at three different points of articulation: labial, dental and velar in a variety of syllabic positions and in different vowel contexts. The subjects were presented with a list of words embedded in the carrier sentence "Diga _____ cada vez" ('say _____ each time') for the Castilian speaker and in the sentence "Diga _____ muchas veces" ('say _____ many times') for the Andalusian speaker. The Castilian speaker read each utterance five times, while the Andalusian speaker read each utterance three times. Reported here are results for the utterances in Tab. I.

Table I.

	Castilian	Andalusian
CASABA	[kasáβa]	PASABA
TASATA	[tasáta]	TASATA
PASBAPA	[pasβápa]	PASAPA
PESEPE	[pesépe]	PESEPE

Fig. 1 illustrates the spatial position of the tongue-tip (TT) and tongue-blade (TBL) movements associated with Castilian and Andalusian /s/ - the trajectories are averages of five tokens in Castilian and three tokens in Andalusian.

It can be seen very clearly from the displays in this figure that the tongue behaves very differently in the two dialects. In Castilian the tongue tip moves mostly vertically from the low position for the vowel /a/ toward the alveolar region. At the point of achievement of the target for the /s/ tongue tip and tongue blade are at nearly the same height, which, given that the tongue blade does not move a great deal from its original position for the preceding vowel, may be interpreted as a confirmation of the apical character of /s/ in Castilian. The picture in Andalusian, on the other hand, is rather different. The tongue tip moves slightly forward and upward from its position for the vowel /a/ toward the dental region, but even at its maximum position or target, the tongue tip is still at a much lower height than the tongue blade, which, as in Castilian, does not move much from its position for /a/ to the /s/ target.

We have seen, thus, that the tongue behavior in Castilian and Andalusian /s/ are clearly different and that the articulatory trajectories obtained in this experiment are in accordance with previous descriptions

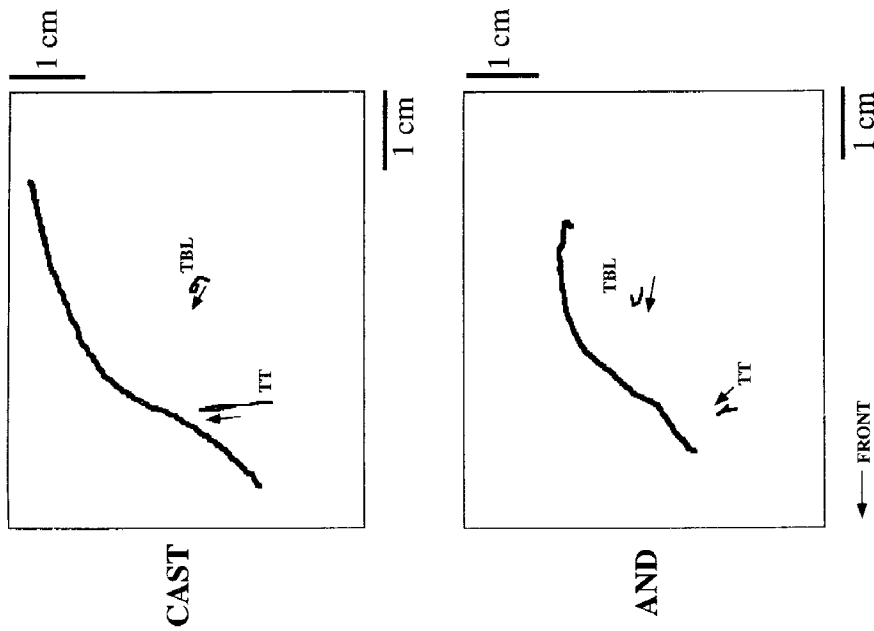


Figure 1. Spatial representation in XY space of tongue coil movement trajectories for the VCV portion of Castilian pAS(b)Apa (top) and Andalusian pASAPA (bottom). A trace of the palate for each subject is displayed over the coil trajectories as visual help, although the position of the palates with respect to the trajectories is only approximate and should not be taken as an indicator of constriction degree. The arrows indicate the direction of the movement for each coil.

of the apicoalveolar versus predorso-dentoalveolar opposition. In order to show indications of gestural reduction, however, we need to look at the dynamic properties of the gestures involved in the achievement of the particular articulatory configurations. For that purpose, the data were analyzed as follows.

The movement of the TT and TBL coils were separated into X (horizontal, along the front/back dimension) and Y (vertical, along the high/low dimension) channels. These channels, over time, were displayed

simultaneously with the corresponding speech signal. First derivatives were obtained for each channel in order to get an estimate of the movement velocity profiles. For each token, the VSV portion of the target word was analyzed and three different sets of X and Y measurements were obtained: displacement, or difference in cm between the tongue position for the preceding V and the target for the S; peak velocity of the articulator during the closing gesture from V to S; target interval, identified as the time interval between acoustic onset for the S and the maximum point of articulator movement or target. Fig. 2 provides an example of how the three events were identified.

Articulator displacement is an indication of the extent of the movement from the previous vowel to the target associated with the consonant, which can provide an estimate of the change in tongue position associated with /s/. Peak velocity is the point of maximum velocity in the movement from the vowel to the consonantal target and

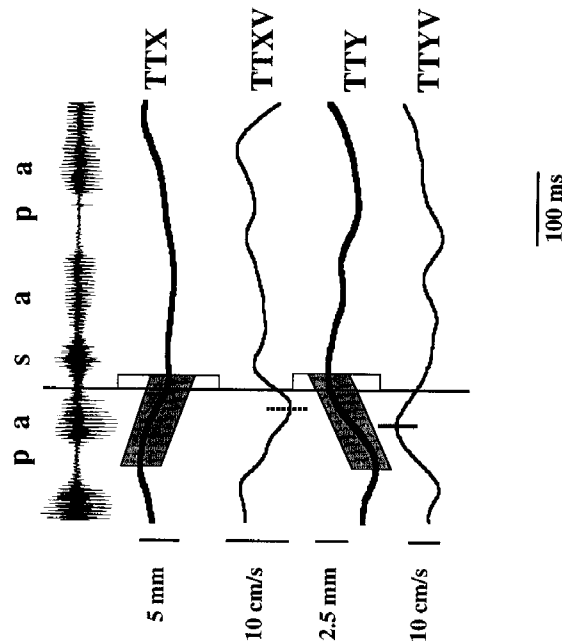


Figure 2. Display over time of acoustic and physiological signals for Andalusian 'pasapa'. The thicker traces represent the movement of the tongue-tip coil in the horizontal dimension (TTX) and in the vertical dimension (TTY). In the TTX trace, a downward movement represents a forward movement of the tongue and an upwards movement stands for a backward tongue movement (for ex. the tongue is at a relatively back position for [a] and moves forward (down in the signal) to make the /s/ constriction). The thinner traces show the corresponding velocities (TTXV and TTYV). The vertical line that crosses all signals indicates the acoustic onset for /s/. The filled boxes correspond to the displacements, the clear boxes to the target interval and the smaller striped lines in the velocity traces to the peak velocity values in the closing gestures.

it can be seen as an indication of the articulator speed during the formation of a constriction. The target interval has to do with the phasing between the two gestures involved in the production of /s/: the separation of the vocal folds in the larynx, which allows heavy airflow through the mouth, and the tongue-tip gesture in the oral cavity, which creates the narrow constriction associated with fricatives.

Everything else being equal, we should expect the tongue-tip displacement in Castilian /s/, because of its apicoalveolar nature, to be larger than in Andalusian in the vertical dimension, whereas Andalusian /s/, by virtue of being dentoalveolar (that is, a more fronted position), should show a larger horizontal displacement than in Castilian. Correspondingly, the velocities would be expected to be larger for Castilian than for Andalusian in the Y dimension, but the other way around in the X dimension. As for the target interval, the phasing between the lingual and the laryngeal gestures should perhaps be more synchronous in the Y dimension for Castilian and in the X dimension for Andalusian.

If, however, there is a reduction in the magnitude of the tongue-tip gesture in Andalusian, then we might expect small displacements in this dialect, even in the horizontal movement. Accordingly, peak velocities should also be lower in Andalusian than in Castilian, even in the X dimension. Finally, a reduction in magnitude in the tongue-tip gesture of Andalusian /s/ could be associated with a longer target interval in this dialect, which could indicate a delay in the phasing of the lingual and the laryngeal gestures.

Tab. II displays articulatory data corresponding to the TT coils during /s/ in the utterances in Tab. I. For the Castilian data, each figure represents an average of five tokens, while in the Andalusian data each figure is an average of three tokens.

Table II.

		Displacement (cm)		Velocity (cm/s)		Target Interval (ms)	
		X	Y	X	Y	X	Y
CAS	CASABA	0.47	1.2	5.03	14.28	25.41	13.20
	TASATA	0.05	0.54	1.11	8.93	55.71	5.02
	PASBAPA	0.36	1.48	7.57	20.10	2.99	9.46
AND	PESEBEPE	0.07	0.91	-1.4	12.32	12.41	9.05
	PASABA	0.51	0.5	6.56	5.36	21.1	15.46
	TASATA	0.17	0.18	3.25	3.16	31.19	17.46
	PASAPA	0.38	0.38	5.33	4.62	-3.3	16.86
	PESEPE	0.13	0.26	2.97	4.26	29.21	18.05

The data were analyzed using analyses of variance with two factors: dialect and utterance. A separate ANOVA was performed for each measure: displacement X and Y, peak velocity X and Y, and target interval X and Y. For those analyses that showed significant interactions, individual t-test were performed for each utterance pair using a Bonferroni correction ($\alpha = .0125$). Even though the results in Tab. II cannot be considered definitive because of the small number of tokens per variable, some general trends can be observed with respect to the predictions made above. The utterances will be compared in a pairwise fashion, as illustrated in Tab. I.

The results for displacement show differences in the direction of the prediction. In general, displacements in the X movement are larger for Andalusian than for Castilian, whereas the reverse is the case in the Y dimension: both X and Y show significant main effects for dialect ($F(1, 23) = 24.41, p < .01$ for X and $F(1, 23) = 776.31, p < .01$ for Y) as well as significant interactions. Looking at the values in detail, however, we see that the differences in vertical displacement between the two dialects are large. T-tests show that they are all statistically significant: $t(6) = -18.02, p < .01$ for *casaba/pasaba*, $t(6) = -15.61, p < .01$ for *pasbapa/pasapa*, $t(5) = -15.21, p < .01$ for *pesbepe/pesepe* and $t(6) = -9.62, p < .01$ for *tasata/tasata*. Differences in horizontal displacement, on the other hand, are very small: the pairs *casaba/pasaba* and *pasbapa/pasapa* are statistically non-significant, the *tasata/tasata* pair is barely significant at $t(6) = -3.53, p < .0123$, while the *pesbepe/pesepe* pair is significant at $t(5) = -5.86, p < .01$. It seems as if, in spite of its supposedly dentoalveolar character, /s/ in Andalusian is being produced with very little movement of the tongue-tip, whether in the vertical or in the horizontal dimension. In fact, the actual values of Andalusian vertical and horizontal displacements are rather similar, which seems to indicate just a slight upward and forward movement of the tongue from the position for the vowel toward the dental region.

In terms of peak velocity, the results are highly correlated with the results for displacement: here also both X and Y show significant main effects for dialect ($F(1, 23) = 23.42, p < .01$ for X and $F(1, 23) = 457.67, p < .01$ for Y), as well as significant interactions. Again we see that, in most cases, the peak velocity of the tongue tip in its movement from the vowel to the /s/ target is higher in Andalusian than in Castilian in the horizontal dimension, but higher for Castilian than for Andalusian in the vertical dimension. But also again a similar discrepancy between X and Y can be observed as in the displacements. The differences between Castilian and Andalusian in the vertical dimension are always statistically significant: $t(6) = -12.5, p < .01$ for *casaba/pasaba*, $t(6) = -14.52, p < .01$ for *pasbapa/pasapa*, $t(5) = -7.17, p < .01$ for *pesbepe/pesepe* and $t(6) = -9.22,$

$p < .01$ for *tasata/tasata*. The results for the horizontal dimension, on the other hand, are more variable: the *casaba/pasaba* pair is non significant, the *pasbapa/pasapa* pair is barely significant at $t(6) = 3.57, p < .0119$, while the *tasata/tasata* and *pesbepe/pesepe* pairs show significant differences at $t(6) = -3.89, p < .01$ and $t(5) = -7.5, p < .01$, respectively. It seems to be the case, then, that the tongue tip in Andalusian is not only moving very little, but also rather slowly.

Finally, differences in target interval or phasing between the two dialects also seem to indicate a trend in the predicted direction. Generally, the lag between acoustic onset of /s/ and achievement of the tongue-tip target is longer in Castilian than in Andalusian for the horizontal dimension, even though neither the main effect for dialect nor the interaction were significant; the utterance main effect, however, was significant ($F(3, 23) = 9.01, p < .01$). Individual utterances differ considerably in both dialects, which suggests a lack of consistency in the achievement of a target in the horizontal dimension. In the vertical dimension, on the other hand, the figures are much more consistent across utterances. Here, Andalusian shows a longer interval than Castilian in all cases. From a statistical point of view, the ANOVA showed a significant main effect for dialect ($F(1, 23) = 6.44, p < .018$) but no significant interaction between dialect and utterance.

5. Interpretation of results in terms of reduction of gestural magnitude

As we said, the results presented above cannot be considered conclusive as to the reduced nature of the tongue-tip gesture of Andalusian /s/. A larger corpus of data is required to confirm or refute the reduction hypothesis with certainty. However, the data do show that, compared with Castilian /s/, Andalusian /s/ is produced with very little movement of the tongue-tip, in the horizontal as well as in the vertical dimensions. They also show that whatever movement there is, is slower than in the other dialect, as demonstrated by the very low values for peak velocity in Andalusian Y movement and the almost negligible values for the X dimension. On top of that, there is some indication that there is a lag in the phasing between the oral and the laryngeal gestures associated with Andalusian /s/, at least in the vertical dimension. All these factors might point to a rather wide constriction degree for /s/ in this dialect.

Nevertheless, it is possible that, because of the predominant alveolar nature of Andalusian /s/, the tip is not the most appropriate part of the tongue for measuring constriction degree for this consonant. Perhaps we should be looking at a more posterior part of the tongue in order to appreciate the actual constriction degree for /s/. Looking at

Figure 1 we see that the tongue-blade coil moves just about as little as the tongue-tip coil in Andalusian. It is also not very different from the overall extent of the movement of the tongue-blade coil in Castilian. Still, the constriction might conceivably be realized at some point on the tongue between the positions of the TT and TBL coils, in which case neither TT nor TBL would be giving us the best estimate of /s/-related tongue movement. It seems unlikely, however, that a large movement of the tongue at the predorsal level would have such little effect on either the tongue tip or the tongue blade, especially since there seems to be no evidence that the predorsum functions as a separate articulator in the dialect. Unfortunately, the issue cannot be pursued directly with the available data.

It has been observed, however, that, at least in English and Castilian Spanish, /s/ is generally associated with a strong movement of the jaw (Keating *et al.* 1990; Romero in preparation). Apparently, such jaw movement, both in the vertical and the horizontal dimensions, contributes to the achievement of the particular tongue configuration necessary for the production of /s/. Thus, if Andalusian /s/ did not show signs of reduction, but rather our coils did not capture the relevant part of the tongue that makes the constriction, then we might expect a similarly strong jaw movement to be associated with Andalusian /s/ as with the reported English and Castilian cases. In order to test that possibility, estimates of jaw displacement and velocity were obtained for the two dialects and compared. Subject differences aside, the results show that the displacement of the jaw, both in the vertical and the horizontal dimensions, are always significantly larger for the Castilian speaker than for the Andalusian speaker. Also, the X and Y velocities are always significantly higher for Castilian than for Andalusian. Thus, to the extent that jaw movement is an indicator of tongue activity for /s/, also here Andalusian shows less of it than Castilian.

Again, such characteristics may or may not be a sign of a reduced tongue-tip gesture in Andalusian /s/. We have to keep in mind, however, that the Andalusian /s/ we have been looking at appears always in stressed syllable-initial position. Of all possible positions, stressed syllable-initial is the one where we would expect the least amount of reduction to take place. One would expect that the observed characteristics of Andalusian syllable-initial /s/ would be affected by possibly universal weakening effects in syllable-final or unstressed positions. Given the nature of Andalusian /s/ in syllable-initial position, it is not hard to imagine how a reduction in its magnitude in certain weak environments would lead to a nearly complete disappearance of the tongue-tip gesture: even less tongue-tip displacement and at a slower speed than we have observed in syllable-initial position would most likely result in almost

no movement at all in syllable-final or other weak positions. Moreover, if we consider the fact that it is not uncommon to hear [h] as a substitute even for syllable-initial /s/ in certain areas of the dialect and in very fast, careless speech, we can see how weaker syllabic positions would easily lead to generalized loss of the lingual component of /s/. The differences in gestural phasing or target interval also seem to be pointing in that direction.

As outlined in section 1, many different realizations of the same aspiration process can be found in Andalusian, depending on the area or on other factors such as style, rate, etc. However, most of the variation can be reasonably explained if we start from the premise that /s/ aspiration is indeed the result of a process of reduction in the magnitude of the lingual gesture of the /s/. Whether such reduction is caused by the articulatory nature of this sound in Andalusian (as suggested in Malmberg 1950 for another aspirating dialect) cannot be proved here, but if the articulatory characteristics of Andalusian syllable-initial /s/ that we have seen are to be considered normal (that is, not reduced), then perhaps one could speculate that a predorso-dentoalveolar /s/ is not, in evolutionary terms, what could be considered a 'good' /s/ and is, consequently, likely to be weakened.

If such a speculation is at all correct, then we would expect to find other common phonological processes, whether synchronic or diachronic, that could be explained in similar terms, as suggested in Mowrey & Pagliuca (1987, this issue). In any case, we believe that it is essential, as stated in Faber (1992), to be able to provide experimental data that can, if nothing else, hint at the correctness of the speculation.

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Notes

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1 Throughout this paper, the terms *aspiration* and */s/-aspiration* will refer to the historical process by which syllable-final /s/ is lost and, in broad terms (see below) replaced by [h]. *Phonetic aspiration*, on the other hand, will be used to refer to the

phonetic phenomenon characterized by the presence of a puff of air following the release of a stop consonant, as in English 'ten' [tʰɛn] or 'cat' [kʰæt].

² In this respect, it is interesting to note that another laminodental segment, the spirantalized dental [θ] is also commonly reduced in certain environments, both in Andalusian and in Castilian, especially in final position as in "verdad" /berdád/ → [berdáθ] 'truth' but also in intervocalic position in, for example, certain past-participle forms, e.g. "cantado" /kantádo/ → [kantáθ] 'sung' (Alecros Llorach 1961)

References

- ALARCOS LLORACH, E. (1961), *Fonología Española*, Madrid, Gredos.
 ALONSO A. (1969), *De la Pronunciación Medieval a la Moderna en Español*, Madrid, Gredos.
 ALVAR M. (1955), "Las hablas meridionales de España y su interés para la lingüística comparada", *Revista de Filología Española*, 39:284-313.
 BROWMAN C. & L. GOLDSTEIN (1989), "Articulatory gestures as phonological units", *Phonology*, 6:201-251.
 BROWMAN C. & L. GOLDSTEIN (1990), "Tiers in articulatory phonology, with some implications for casual speech", in J. KINGSTON & M. BECKMAN, eds., *Papers in Laboratory Phonology*, I (1990), London, Cambridge University Press:341-376.
 BROWMAN C. & L. GOLDSTEIN (1991), "Gestural structures: Distinctiveness, phonological processes and historical change", in I. MATTINGLY & M. STUDDERT-KENNEDY, eds., *Modularity and the Motor Theory of Speech Production* (1991), Hillsdale, NJ., Lawrence Erlbaum Associates:313-38.
 BROWMAN C. & L. GOLDSTEIN (1992), "Articulatory phonology: An overview", *Phonetica*, 49:155-180.
 CARBONERO CANO P. (1982), *El habla de Sevilla*, Sevilla, Biblioteca de Temas Sevillanos, Servicio de Publicaciones del Ayuntamiento de Sevilla.
 CHLUMSKY J. (1929), "L's andalouse et le sort de l's indo-européene en slave", *Slavia*, 7:750-753.
 CHOMSKY N. & M. HALLE (1968), *The Sound Pattern of English*, New York, Harper and Row.
 FABER A. (1992), "Articulatory variability, categorical perception, and the inevitability of sound change", in FERRY W. DAVIS & G.K. IVERSON, eds., *Explanation in Historical Linguistics* (1992), Philadelphia, John Benjamins Publishing Co.:59-75.
 FRAGO GARCÍA J.A. (1983), "Materiales para la historia de la aspiración de la /s/ implosiva en las hablas andaluzas", *Lingüística Española Actual*, 5:153-171.
 GOLDSMITH J. (1981), "Subsegmentals in Spanish phonology: an autosegmental approach", in W. CRESSEY & D.J. NAPOLI (eds.), *Linguistic Symposium on Romance Languages*, 9 (1981), Washington, Georgetown University Press:1-16.
 GRAMMONT M. (1946), *Traité de phonétique*, Paris, Librairie Delagrave.
 HARRIS-NORTHALL R. (1990), *Weakening Processes in the History of Spanish Consonants*, New York, Routledge.

- JONASSON J. (1971), "Perceptual similarity and articulatory reinterpretation as a source of phonological innovation", *STL-QPSR*, 1:30-42.
 JOOS M. (1952), "The medieval sibilants", *Language*, 28:222-231.
 KEATING P.A. et al. (1990), "Jaw position in English and Swedish VCVs", *UCLA Working Papers in Phonetics*, 74:77-95.
 KIDDLE L.B. (1977), "Sibilant turmoil in middle Spanish (1450-1650)", *Hispanic Review*, 45:327-336.
 KING R.D. (1969), *Historical Linguistics and Generative Grammar*, Englewood Cliffs, NJ, Prentice Hall.
 LAPESA R. (1981), *Historia de la lengua española*, Madrid, Gredos.
 LABOV W. (1974), "On the use of the present to explain the past", *Proceedings of the Eleventh International Congress of Linguists*, vol. 2, Bologna, Il Mulino:825-851.
 LABOV W., M. YAEGER & R. STEINER (1972), *A quantitative study of sound change in progress*, Philadelphia, US Regional Survey.
 MALMBERG B. (1950), "Études sur la phonétique de l'espagnol parlé à l'Argentine", *Études Romanes de Lund*, X.
 MARRERO V. (1990), "Estudio acústico de la aspiración en Español", *Revista de Filología Española*, 70:345-397.
 MARTINET A. (1955), *Économie des changements phonétiques*, Berne, Éditions A. Francke.
 MENDEZ DOSUNA J. (1987), "La aspiración de s como proceso condicionado por el contacto de sílabas", *Revista de la Sociedad Española de Lingüística*, 17:15-35.
 MOWREY R. & W. PAGLIUCA (1987), *The reductive character of phonetic evolution*, Unpublished manuscript, State University of New York in Buffalo.
 MOWREY R. & W. PAGLIUCA (1995), "The reductive character of phonetic evolution", *Rivista di Linguistica*, 7, 1:39-127.
 NARBONA JIMÉNEZ A. & R. MORILLO-VELARDE PÉREZ (1987), *Las hablas andaluzas*, Córdoba: Publicaciones del Monte de Piedad y Caja de Ahorros de Córdoba.
 OHALA J. (1974), "Phonetic explanation in phonology", in A. BRUCK, R. FOX & M. LAGALY, eds., *Papers from the Parasession on Natural Phonology* (1974), Chicago, Chicago Linguistic Society:251-274.
 OHALA J. (1981), "The listener as a source of sound change", in C.S. MASEK, R.A. HENDRICK & M.F. MILLER, eds., *Papers from the Parasession on Language and Behavior* (1981), Chicago, Chicago Linguistic Society:178-203.
 PAGLIUCA W. (1982), *Prolegomena to a Theory of Articulatory Evolution*, Unpublished doctoral dissertation, State University of New York in Buffalo.
 PERKELL J. et al. (1992), "Electro-magnetic midsagittal articulometer systems for transducing speech articulatory movements", *Journal of the Acoustical Society of America*, 92:3078-3096.
 ROMERO J. (1995), *Gestural Organization in Spanish: an Experimental Analysis of Spirantization and Aspiration*, Ph.D. dissertation, University of Connecticut.
 SALVADOR G. (1977), "Unidades fonológicas vocálicas en andaluz oriental", *Revista Española de Lingüística*, 7:1-23.
 STRAKA G. (1964), "Remarques sur la 'désarticulation' et l'amuissement de l's implosive", in J. RENSON, ed., *Mélanges de linguistique romane et de philologie médiévale, offerts à M. Maurice Delbouille* (1964), Gembloux, Éditions J. Duculot:606-628.

- TERRELL T. (1981), "Diachronic reconstruction by dialect comparison of variable constraints: s-aspiration and deletion in Spanish", in D. SANKOFF & H. CEDERGREN, eds., *Variation Omnibus* (1981), Carbondale, IL, Linguistic Research Inc.:115-124.
- TORREBLANCA M. (1989), "La /s/ implosiva en español: Sobre las fechas de su aparición", *Theasurus*, 44:281-303.
- VÄÄNÄNEN V. (1963), *Introduction au latin vulgaire*, Paris, Klincksieck.
- VAZ DE SOTO J.M. (1981), *Defensa del habla andaluza*, Sevilla, Cuadernos de Cultura Popular, Consejería de Cultura de la Junta de Andalucía / Edisur.
- WIDDISON K.A. (1991), *The Phonetic Basis for /s/ Aspiration in Spanish*, Unpublished doctoral dissertation, University of California at Berkeley.
- WIDDISON K.A. (1992), "Hacia los orígenes de la /s/ aspirada en español", *Estudios de fonética experimental*, V, Barcelona, Promociones Publicaciones Universitarias:35-60.
- WIDDISON K.A. (1995), "An acoustic and perceptual study of the Spanish sound change s > h", *Revista de Lingüística*, 7,1:181-196.
- ZAMORA VICENTE A. (1969), *Dialectología Española* (2nd ed.), Madrid, Gredos.