A Q/Cue-Theoretic Approach to Cross-dialect Spanish <st> Production

Amber Galvano

1. Introduction

The shift from pre- to post-aspiration in intervocalic /s/ + voiceless stop sequences (i.e., /pasta/, ['pah.ta] → ['pa.t^{h}a]) has become synonymous with Andalusian Spanish in the sociophonetic literature. New data suggests that this change may be in early stages in Buenos Aires Spanish, showing variably pre- and/or post-aspirated realization of intervocalic <st>. Previous accounts within Articulatory Phonology (AP) (Browman & Goldstein 1986) explain the shift from pre- to post-aspiration as the product of gestural phasing and extensive coarticulatory overlap (e.g., Parrell 2012, Torreira 2007, 2012). A novel representational approach drawing from Q-theory (Inkelas & Shih 2013), Cue-Based Features (Pfiffner 2021), and Exemplar Theory (Johnson 1997), explains the development of these sequences through changing exemplar weights of the phonetic cues associated with the /s/ and /t/ segments (the coronal context being the hypothesized origin point; Ruch & Peters 2016). These weights are phonologized and temporally ordered according to subsegmental q's, or feature bundles, associated with each segment, or Q. The interaction of the these frameworks offers a fruitful synchronic model for transitional productions with both pre- and post-aspiration as well as where changes in place and manner occur, and helps make predictions about how /st/ has evolved and where they might be predicted to shift next.

2. Language Background

2.1. Western Andalusian Spanish

"Andalusian Spanish" is an understudied and stigmatized macrodialect spoken in Andalusia, the southernmost and most populous of Spain's autonomous communities. Andalusian Spanish is characterized by coda /s/-lenition (e.g., *pasta*, ['pa.t^{h}a]), syllable-initial /s/ variation (e.g., *policía ambicioso*, [po.li.'(θ/s)ia.am.bi.'(θ/s)jo.(s/θ)o]), velarization of word-final /n/ (e.g., *como pan*, ['ko.mo paŋ]), mid-vowel lowering and harmony (e.g., *nenes*, ['nɛ.nɛ]), and stop-fricative coalescence (e.g., *las damas*, [la 'ðа.mah]), among others (Villena-Ponsoda 2008). Western Andalusian Spanish (WAS) refers to the subvariants spoken in the provinces of Huelva, Seville, and Cádiz. Post-aspiration of /sp st sk/ has become one of its most distinctive characteristics.

2.2. Buenos Aires Spanish

Buenos Aires Spanish (BAS) is a variety contributing to the "Cono Sur" macrodialect of southern South America, spoken in Buenos Aires, Argentina. Its distinctive traits include coda /s/-lenition (e.g., pasta, [pah.ta]), *seseo* (e.g., *policía ambicioso*, [po.li.'sia.am.bi.'sjo.so]), and *ʃeísmo/ʒeísmo* (e.g., *le llamo a mi yerno*, [le '(ʃ/ʒ)a.mo a mi ('ʃ/ʒ)eɾ.no]). Palatal variation (e.g., Chang 2008) and coda /s/-lenition (e.g., Lipski 2012) are among its best-known characteristics.

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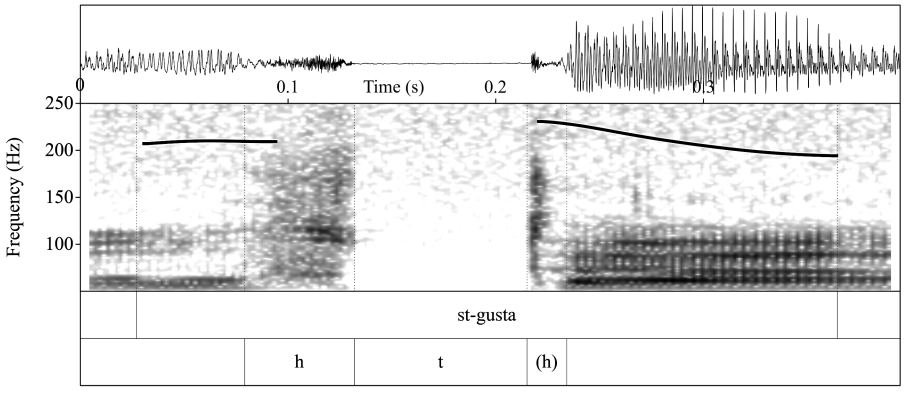
3. Theoretical background

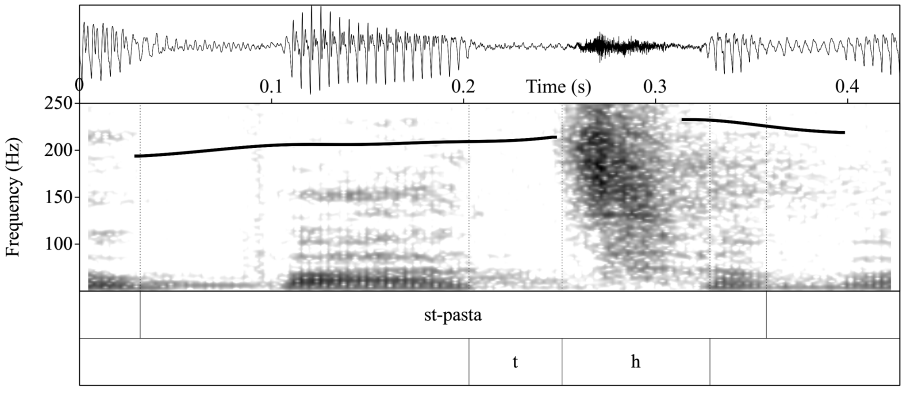
3.1. Coda /s/-lenition

Two primary stages of coda /s/-lenition in the /s/ + voiceless stop context are typically understood for Western Andalusian Spanish – pre- and post-aspiration – diachronically linked but also seen simultaneously in some synchronic data (e.g., Galvano & Henriksen 2023, Ruch 2008). Pre-aspiration, defined broadly as a glottal fricative preceding the stop closure (e.g., [pahta]), is as a feature of Andalusian Spanish broadly (Gerfen 2002) and in regional varieties of Latin America (Lipski 2012). A representative spectrogram for each production type is shown in (1) and (2) below.

(1) Sample waveform and spectrogram for pre-aspiration from a BAS speaker (VOT: 19 ms).



(2) Sample waveform and spectrogram for post-aspiration from a WAS speaker (VOT: 71 ms).



Several accounts of Western Andalusian /st/ have further noted affricate productions (i.e., [ts]) (Del Saz 2019, Ruch 2008, Vida-Castro 2015, 2022). The data below in Section 4 introduces the co-occurrence of pre- and post-aspiration in Buenos Aires /st/ production.

3.1.1. Coda-/s/ lenition in Articulatory Phonology

Articulatory Phonology (AP) (Browman & Goldstein 1986) has been the primary framework for describing the changes in Spanish coda /s/. I aim to build from these accounts using recent theoretical tools to capture the full range of variation in production over the course of sound change. In AP, the smallest phonological unit is the gesture, defined as a discrete, dynamic, and public action of the vocal tract. Gestures temporally overlap, but are said to be 'context-free' and thus coarticulation can be thought of in terms of extensive temporal overlap between gestures (Fowler 2015). Of note, this framework was theorized in the late 1980s/early 1990s, at a time when subsegmental approaches like Q-theory did not yet exist (cf. Steriade (1993) on Aperture Theory).

In AP, the linear order of adjacent phonetic events may be affected by the "phasing" of related gestures (Saltzman & Byrd 2000). In the case of /sC/, the time-course of aspiration with respect to stop closure

depends on the type of overlap between the tongue tip closure and glottal spreading gestures. If the tongue gesture is contained temporally within the glottal gesture, and shorter than it, a glottal fricative is produced; its surface location(s) then depends on whether the start or end of the gestures (or neither) is concurrent. The change from pre- to post-aspiration, under AP, is therefore initiated through a reorganization of these gestures from initiating sequentially, where stop closure follows glottal spreading, to simultaneously (Parrell 2012, Torreira 2012). This shift is said to be the result of increased speech rate and the relatively greater stability of simultaneous gesture onset.

3.1.2. Perceptual accounts of coda /s/-lenition

Ruch and Peters (2016) additionally propose a three-step pathway by which pre- becomes post-aspiration, drawing from biomechanical and perceptual sources. First, high intraoral air pressure from the lengthened stop closures in pre-aspirated [hp ht hk] result in unusually long VOT: [hp^{h} ht^{h} hk^{h}]. Then, this lengthy VOT is noted as perceptually salient by listeners, especially in the coronal context. Finally, "actuation" occurs when speakers exaggerate this long VOT. This view dialogues well with AP, in that intraoral air pressure may be an additional reason, alongside speech rate and gestural stability, why gestural phasing would shift. However, Ruch and Peters importantly highlight a predicted intermediate stage, where both pre- and post-aspiration occur. This contradicts claims that the shift to post-aspiration is abrupt and rate-induced (cf. Parrell 2012).

4. Data

Data from 21 Andalusian speakers from Jerez, Spain and 20 speakers from Buenos Aires were extracted from spontaneous speech elicited via sociolinguistic interviews, carried out by research assistants native to each respective region. Word-medial and word-final tokens were visually inspected and annotated according to production type by two trained phoneticians. Per Quilis (1981) and Henriksen et al. (2023), tokens with "long VOT", taken to contain bona fide post-aspiration, had a VOT of at least 29 ms. Frequency counts for each attested production type by dialect are given in (3).

(3) Frequency of each token type by dialect

Production type	WAS	BAS
[st]	1	153
[ht] or [t]	110	1,523
[ht^{h}]	49	666
[t^{h}]	1,363	0
[ts]	252	0
[tʃ]	45	2
[s]	162	41

5. Proposal: Q's + Cues

5.1. Introducing the framework

The current proposal integrates recent ideas about the relationship between segments and their subparts (Q-theory) and between phonetic cues and phonological features (Cue-based Features, or CbF). This combination requires some restrictions on how the component parts of phonetics-phonology interface interact. Some have previously argued for no demarcation point between "phonetics" and "phonology" (e.g., Ohala 1990), while others argue for multiple points of contact (e.g., Ladefoged 1988), and others still for an interface somewhere in-between (e.g., Kingston & Diehl 1994, Steriade 1997). In the proposed model, as in Q-theory, segments are referred to as Q's, while subsegmental q's are a stand-in for feature bundles. As in CbF, cues associate with feature bundles as a whole, depending on their function in phonological contrasts. Like in Q-theory, each q can associate to one Q at a time, making features segment-specific. However, I propose features may be repeated at adjacent q's to capture the time-course of segment production.

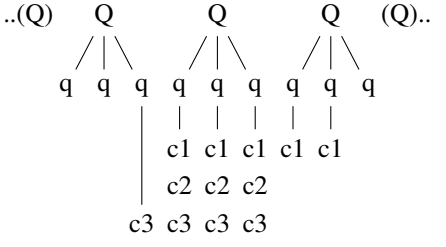
One potential sticking point is that in CbF, cues can associate to a single segment, the transition between segments, and/or neighboring segments. Since neighboring segments have their own respective cues and features, this suggests a potential crossing of association lines. However, in order to maintain the well-supported function of cues beyond the immediate segment, I suggest that instead of one cue exerting influence on units of varying distance, cues are reiterated at every q where they are relevant. The same set of cues may be observed at multiple q's; each q is like a discrete reference point for the acoustic signal. An effect of this is that the q (and thus features), rather than the Q, acts as the "core" of the representation. This will be useful for explaining gradual processes that generate changes in segment identity (see 6.1.3).

Finally, as CbF and Q-theory are both exemplar-based, the mechanism for how cues get their weights, and how the makeup of q's and Q's changes over time, remains essentially the same as in the original theories (see 5.2). However, an important characteristic of Q/Cue-based features comes from Garrett and Johnson (2013): the portion of the exemplar space employed in production is contained within and smaller the perceptual space. The former gets represented in the present model.

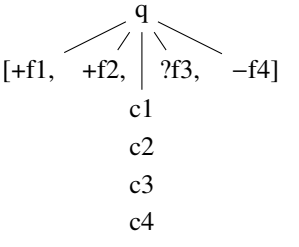
5.2. Q's and q's; cues and features

In Q/Cue-based features, the default is three q's per one Q (4), but for some phenomena this ratio may be altered (see Garvin et al. 2020). A q is also actively associated to all cues with a weight above 0 during its fraction of the given segment. Cues in q bundle are stacked here, but their order is not meaningful.

(4) Schematic relationship between Q's, q's, and cues, where "c" stands for cue



(5) Schematic breakdown of q and cue bundles, where "f" stands for feature and "c" for cue



As in Q-theory, each q can be deconstructed into a bundle of phonological features (5). For a cue to be active, its weight must contribute to at least one active or ambiguous feature in the q. Dormant cues (in gray) come from past speech encounters with very weak ties to the dominant representation and no present influences on feature activation. Listed cues and features will have been derived from speech events where they interacted, directly or indirectly; hence VOT may trade off with duration of pre-aspiration, and activation of one feature may enhance or hinder activation of another (e.g., [−spread glottis] sets the stage for ambiguous or active [voice]).

As in CbF, the influence of exemplars is reflected in cue weights, and cumulative changes in cue weights can change the activity label of features. Building from this, changes to features in each bundle can lead to changes in Q's. If exemplars are associations between auditory percepts and category (linguistic, social, visual, etc.) labels (Johnson 1997), and acoustic cues are auditory percepts given acoustic labels, the exemplar "space" then includes "clouds," of speech exemplars that match in terms of their stored attributes; the more points of connection, the tighter-knit the cloud, and the greater number of closely linked exemplars, the more active this cloud becomes in an individual's representation. Drawing from Pfiffner (2021), groupings of cues in the exemplar space with overlapping labels give rise to features. The present *range* of exemplar cloud densities then influences "underlying" representations, which contain a range of available cue weights (see 6.2).

6. A Q/Cue-based representation of Spanish <st>

6.1. Surface representations

In this section, I present surface representations (SRs) for a hypothetical speaker at three stages of change, beginning where pre-aspiration is dominant. At each, I start with a more abstracted look at /sC̥/

in context, and then zoom in to show more precise cue weights and features within each bundle. Bolded cues have a weight greater than 0. See 6.2 for discussion of corresponding underlying representations.

Starting from the point of /s/-lenition via pre-aspiration, through the shift to post-aspiration and affrication, I take the cues and (binary) features shown in (6) to be relevant.

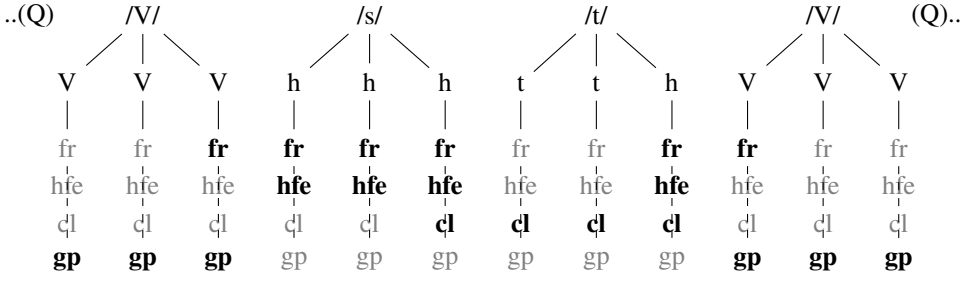
(6) Selected cues and features for the Q/Cue-based Features approach to Spanish <st>.

CUES	FEATURES
frication (fr)	spread glottis (sg)
high frequency energy (hfe)	continuant (cont)
closure duration (cl)	anterior (ant)
glottal pulsing (gp)	voice

6.1.1. Dominant pre-aspiration

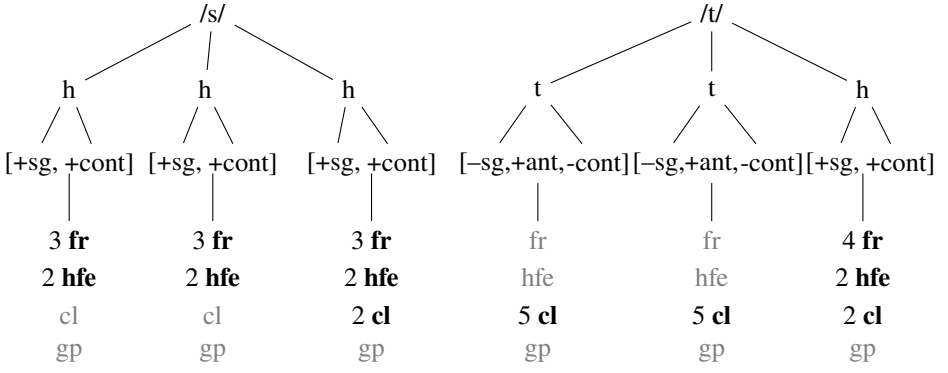
(7) shows a possible SR for a speaker who predominantly pre-aspirates /st/. In this case, glottal pulsing is only weighty during the flanking vowels. Frication gets weight (**fr**) during the final third of the initial vowel, corresponding to breathiness, and frication is maintained throughout /s/. High frequency energy (**hfe**) is also weighted during the /s/, and closure duration (**cl**) is factored into the length of pre-aspiration, about equal in length to the closure here. In the final third of the stop closure, **fr** and **hfe** again have weight for a brief period corresponding to singleton-like VOT, ≤20 ms. This VOT may bleed into the following vowel, indicated by the final bolded **fr**.

(7) Surface representation for an individual who pre-aspirates intervocalic <st>



(8) below specifies the changes in cue weights and the activity of the features in each bundle. Of note, closure duration has greater weight during the closure than preceding it, and VOT gets a slightly higher weight than pre-aspiration, because it is more temporally dense, and because exposure to an increasing number of perceptually impactful lengthy VOT tokens is said to be key to change (per Ruch & Peters 2016). However, at this stage exemplars with singleton-like VOT still control the final q of the /t/ segment.

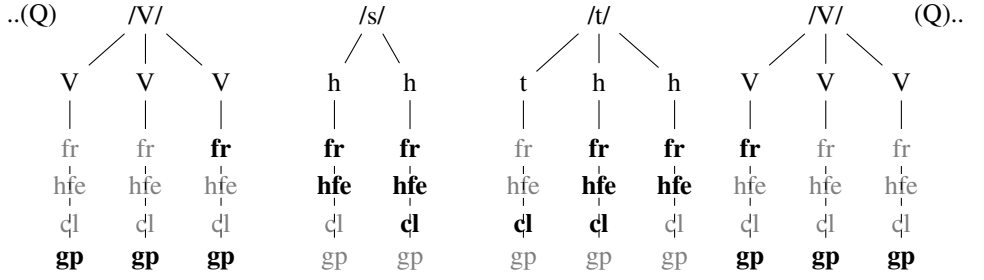
(8) Detailed surface representation with pre-aspiration for /s/ and /t/ only



6.1.2. Dominant pre- and post-aspiration

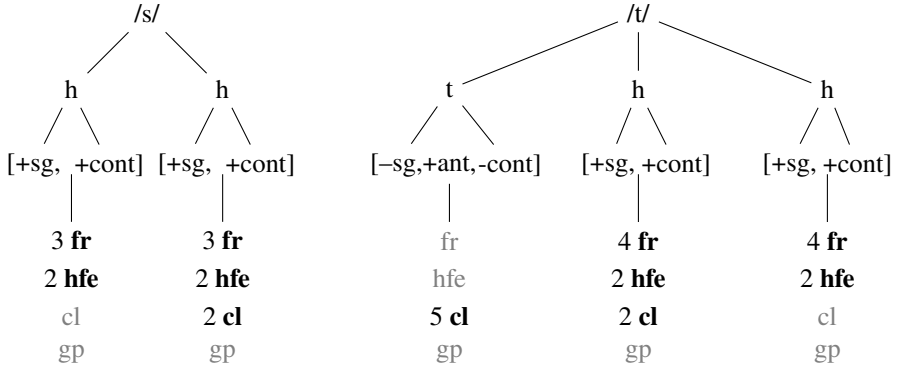
Once the dominant production type has shifted to include both pre- and post-aspiration, which BAS speakers are moving towards (Galvano & Henriksen 2023), there are two primary shifts to the representation at the level of the q, due to the observed trade-off between pre- and post-aspiration length. First, as in (9), /s/ loses a feature bundle, as exemplars with shorter pre-aspiration take over, and the center q of the /t/ segment becomes controlled by exemplars with moderately lengthy VOT (near to 29 ms, per Quilis (1981) and Henriksen et al. (2023)). I propose that when exemplars containing shorter pre-aspiration control the representation, the /s/ loses its ability to host a full three q's. Then, since post-aspiration lengthening is said to correlate with closure shortening (Henriksen et al. 2023, Parrell 2012, Ruch & Harrington 2014), **cl, hfe**, and **fr** are all active at the center /t/ q, reflecting their interrelatedness.

(9) Surface representation for an individual who both pre- and post-aspirates intervocalic <st>



(10) below highlights that, again, closure duration is most weighty during the true closure period (first q of the /t/), with a weight of 5. Moreover, the general presence of frication after the closure (**fr** weight of 4) is more relevant at this stage of change than the fact that spectral energy is concentrated in the high frequency range (**hfe** weight of 2). The relationship between these latter two cues will become relevant in section 6.1.4, with the introduction of affricate variants.

(10) Detailed surface representation with pre- and post-aspiration for /s/ and /t/ only

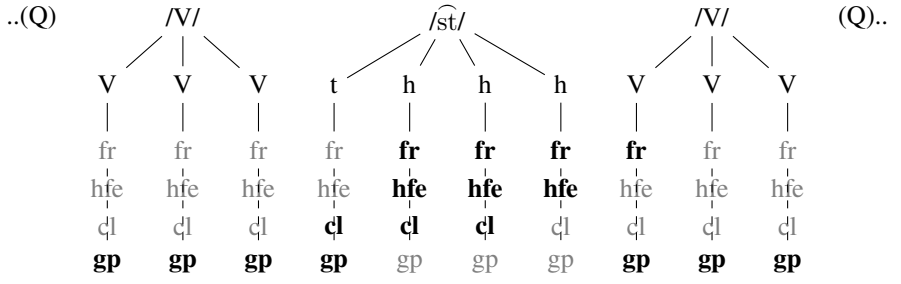


6.1.3. Dominant post-aspiration

When full surface metathesis develops, a pair of changes, one at the level of the q and the other at the level of the Q, is proposed. First, in the transition between (9) and (11), the /s/ feature bundles are reduced from two to one, as pre-aspiration continues to dwindle. Eventually, this remaining bundle too delinks from the segment, as in (11), given that there is point in the sound change when pre-aspiration of any length is no longer present in highly active /st/ exemplars. Once this step has occurred, the slot for /s/ and its features is "empty" (i.e., all its features are dormant), and thus it is stranded in the prosodically weak coda position. These dormant features, still occupying some representational space, need a host and thus glom onto the segment originally called /t/; as a result, the entire unit gets reinterpreted as a complex segment, with four q's to accommodate an increase in length (see Henriksen et al. (2023)). Shih and Inkelas (2014) have previously suggested that similarity and proximity of segments or subsegments

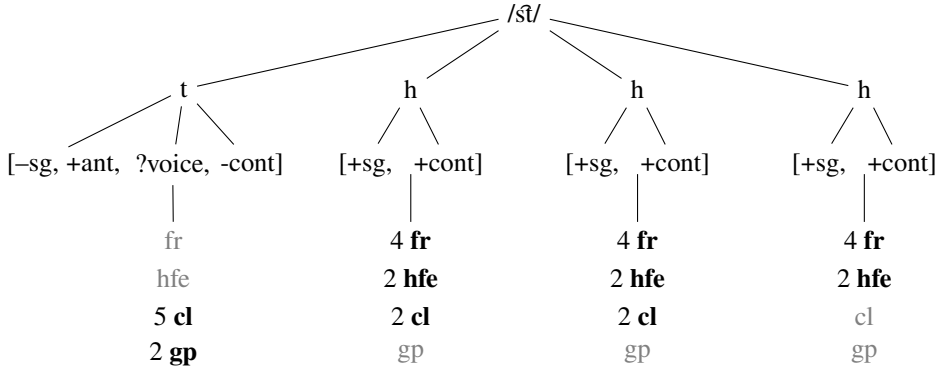
correlates with their likelihood of interacting. This also provides a solution to contradictory observations from previous literature that post-aspirated stops in WAS behave in some ways like an underlying /sC̥/ (Gylfadottir 2015, O'Neill 2009) and in other ways as if a new series of aspirated stops has emerged (Gilbert 2022).

(11) Surface representation for an individual who post-aspirates intervocalic <st>



The main elements to highlight in the more detailed view given in (12) are, first, that glottal pulsing is now introduced at the first q of the new complex /st͡/ segment. This is due to lack of material between the closure and previous vowel, but note that we typically only see partial closure voicing WAS (see Henriksen et al. (2023)). Recall that this first q, which stems from the remnants of the original /s/, is now predominantly controlled by cues to [t] in the exemplar space. For this reason, I include the [voice] feature at the first q, but value it as ambiguous (indicated by the preceding question mark). Second, the [h] features and cues now extend farther leftward, occupying three full q's, reflecting the continued trade-off of lengthening VOT (now upwards of 60 ms; Henriksen et al. 2023) and decreased closure duration.

(12) Detailed surface representation with post-aspiration for /s/ and /t/ only



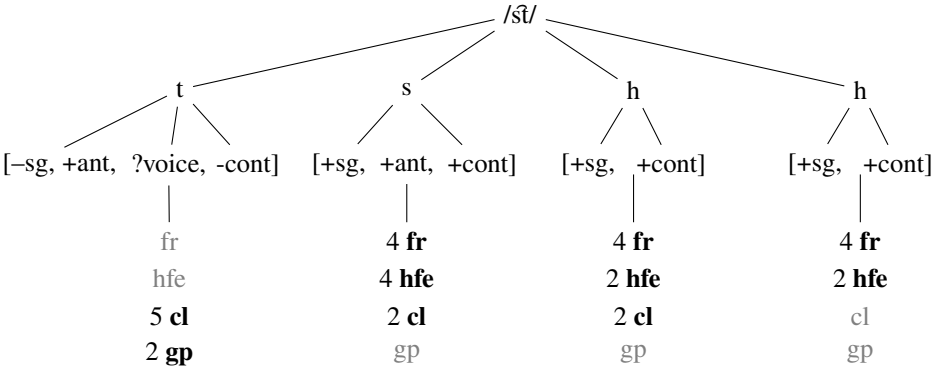
6.1.4. Dominant alveolar affricate

Once post-aspiration becomes the dominant production type, as in contemporary WAS, we expect that the alveolar affricate also becomes a secondarily-dominant production type (in some regions, it may be already the dominant variant; Vida-Castro 2022). To account for cases where a speaker produces the affricate realization, I propose the representation in (13). Only two departures are needed from (12): first, the [anterior] feature becomes active at both the first and second q's, and second, the high frequency energy cue gets a higher weight (4 as opposed to 2) at the second q, in order to reflect a more anterior place for the release.

One reason for these changes may be that some dormant information from the first q in (12), maintained from the old /s/, is being reasserted in a more perceptually salient position, after as opposed to before the stop closure. This complements previous proposals that perceptual salience is key to the propagation of this sound change (Ruch & Peters 2016). Perhaps with the additional introduction of closure voicing observed in post-aspirated tokens, the greater perceptual salience afforded by the concentration of high frequency energy in [ts], as opposed to [t^{h}], also helps to maintain contrast with intervocalic /p t k/, which

are often fully voiced (Lipski 2012). The rise of the affricate may also be socially motivated to some degree, as young women are said to be its most frequent users (Vida-Castro 2022).

(13) Detailed surface representation for affricated /s͡t/



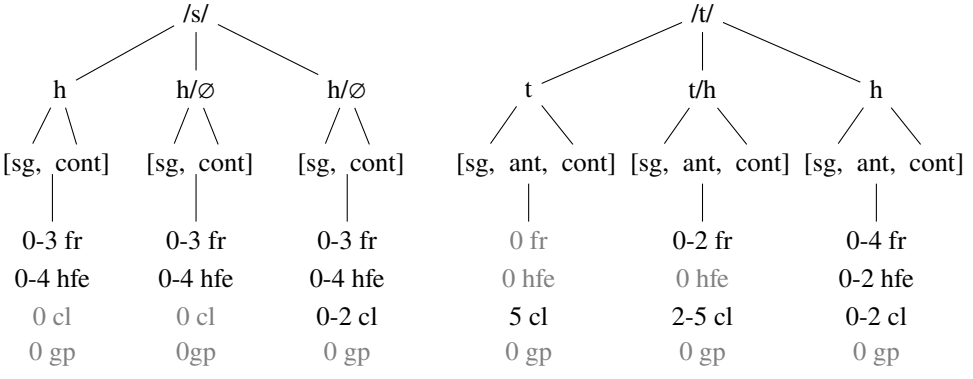
6.2. Underlying representations

In this section I propose two underlying representations (URs) to complement the surface representations given in 6.1: one pre-metathesis and one post-metathesis.

6.2.1. Pre-metathesis

Pre-metathesis, the UR contains two normal-length, three-q segments, as in (14). All features that might arise from cues persisting prior to the loss of pre-aspiration are available to select from during production. Which features are active on the surface depends directly on what speech variants an individual has encountered. The dual label "h/∅" for q's two and three of /s/ would apply once a speaker has encountered variation in the presence and length of pre-aspiration, whereas prior to any shortening of pre-aspiration, all three q's would have "h" labels. Likewise, once lengthened VOT is encountered, the center q for /t/ gets a "t/h" label to reflect that some active exemplars have a longer closure and others a longer VOT.

(14) Underlying representation for /s/ and /t/

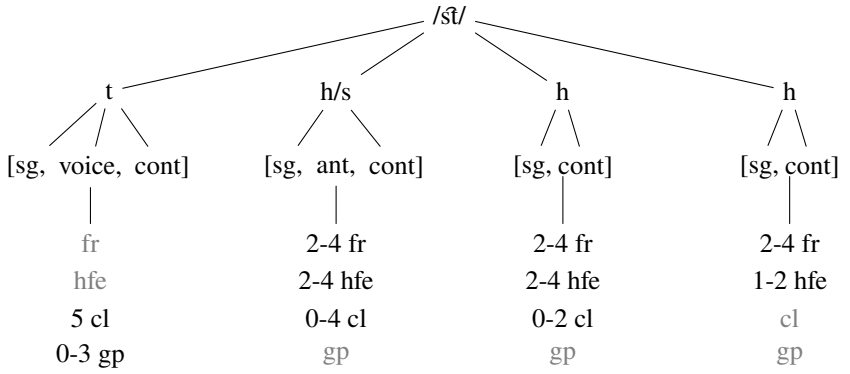


6.2.2. Post-metathesis

When surface metathesis first develops, speakers likely toggle between the URs in (14) and (15). It has been questioned whether pre-aspiration of any length is really *never* produced or heard post-metathesis; for example, all WAS speakers from Section 4 produced some amount of pre-aspiration, some of the time, either alone or alongside post-aspiration. In either case, once the "production" exemplar space expands to include cases of post-aspiration alone, the speaker then has access to a representation like (15). Here, the

first [t] q may feature glottal pulsing, and the final three [h] q's reflect some kind of continuant, varying in how its high frequency energy is concentrated; the [anterior] feature is available at the second q to account for the possibility of the alveolar affricate, once encountered. If over time the affricate strengthens further, q's two and three may take on the composition of q one.

(15) Underlying representation for /st͡/



7. Conclusion

This paper has overviewed the sound change towards post-aspiration (and affrication) of <st> in Andalusian and Buenos Aires Spanish, offering a novel conception of its phonetic and phonological properties that combines pre-existing notions. Motivated by sociophonetic data reflecting different dominant production types and variant distributions in each dialect, I have shown how Q-theory and Cue-based Features together can capture the nuance of this sound change. I have proposed that surface metathesis in WAS corresponds with phonologization of a new complex segment. In doing so, I have implied that q's, containing temporally ordered feature bundles, are key interface points between "phonetic" exemplars (crucially containing acoustic cues) and "phonological" segments. I hope for this work to serve as a jumping-off point for more explicit modeling of how phonetic exemplars may interface tangibly with components of traditional phonology like the segment.

Avenues for expanding this work further might include: a more direct incorporation of other information sources (i.e., visual, social) affecting speech exemplars into the model; a more explicit calculation of exemplar weights and their relationship to individual cue weights; a Max-Ent (Goldwater et al. 2003) style evaluation of which perceptual exemplars are integrated into the proposed production space; a set of OT-style constraints to complement the proposed representations; and an analysis of perceptual data confirming which variants are linguistically and socially meaningful to speakers of each dialect to verify and refine the proposed representational stages (e.g., Gilbert 2022).

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