Gestural Timing and Rhotic Variation in Spanish Codas

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0. Introduction

In Browman and Goldstein’s (1989, 1990, 1991, 1992) theory of Articulatory Phonology, gestures are dynamically, spatio-temporally defined articulatory movements that produce a constriction in the vocal tract. Gestures function not only as units of articulation but also as the primitives of phonological organization. This property sets Articulatory Phonology apart from most theories of phonology which relegate phonetic timing to an implementation component derivationally ordered after the phonology proper. A central claim of the gestural model of Articulatory Phonology is that many phonological processes, such as assimilation, deletion and insertion, can be reduced to two types of modifications occurring in casual speech: reduction in the magnitude of gestures, and temporal realignment of adjacent gestures. Furthermore, the model predicts that overlap between gestures involving different articulators will not affect the trajectory of either gesture, while overlap between gestures involving the same articulator will produce a blending of gestural characteristics, which “shows itself in spatial changes in one or both of the overlapping gestures” (Browman and Goldstein 1990: 362).

This paper explores the role of gestural alignment in the realization of heterosyllabic /rC/ clusters, such as found in árbol /arbol/ ‘tree’ and carne /karne/ ‘meat’, across different Spanish varieties. Many Latin American Spanish dialects are characterized by assibilation, a process whereby an alveolar tap /l/ or trill /r/ is realized phonetically as a strident fricative [F]. While Colantoni (2001) finds no assibilation of coda /r/ in Argentine dialects, data from Argüello (1978) show that the phenomenon is more widespread in the Spanish of highland Ecuador, where assibilation affects homorganic /rC/ clusters in casual speech. As Colantoni points out, Argüello provides detailed phonetic description of the Ecuadorian rhotic phones but “never demonstrates spectrographically that rhotics are assibilated in syllable coda position” (60). In the present study, spectrographic analysis is presented to show that coda assibilation is empirically attested in this variety. An analysis of rhotic variation in Spanish codas is proposed in which the articulatory preference for overlap between adjacent consonantal gestures conflicts with the competing requirement that underlying clusters
be perceptually recoverable. Because it is built directly upon the notion of competition and conflict resolution, Optimality Theory (Prince and Smolensky 1993; McCarthy and Prince 1993a, 1993b, 1995) is an appropriate framework for analyzing cross-dialectal variation in the gestural timing of /rC/ clusters.

This paper is organized as follows. Section 1 reviews previous studies on the realization of /rC/ clusters in Peninsular Spanish and then documents a casual speech alternation between [ɾ] and the assimilated fricative [f] in highland Ecuadorian Spanish. Section 2 investigates the acoustic properties of assimilation via spectrographic analysis of relevant data collected from highland Ecuadorian Spanish speakers. In Section 3, I provide a phonetically motivated account of coda /r/ assimilation using Browman and Goldstein’s gestural model. Section 4 integrates the phonetic explanation into an Optimality-theoretic analysis that captures the attested differences in /rC/ cluster realization across dialects. Section 5 summarizes and concludes.

1. Rhotic variation in Spanish /rC/ clusters

It has long been noted that in Spanish clusters containing /ɾ/, a vowel fragment (a.k.a. svarabhakti, Whitney 1889) typically intervenes between the rhotic and the adjacent consonant (Gili Gaya 1921; Lenz 1892; Navarro Tomás 1918). The data in (1) from Malmberg (1965: 34–8) illustrate svarabhakti in /rC/ clusters in Peninsular Spanish:

1. árboles [ar3.β] ‘trees’
   verdés [er3.ð] ‘green’
   cargar [ar3.γ] ‘to load’
   fuerza [er3.s] ‘force’

Although represented here simply as [?] in narrow phonetic transcription, the svarabhakti fragment has formant structure similar to that of the nuclear vowel appearing on the opposite side of the tap constriction (Quilis 1993: 337–42). Furthermore, the phonetic measurements of Gili Gaya (1921: 277–8) and Malmberg (1965: 10, 35) show that the svarabhakti fragment
varies in duration, often approximating that of an unstressed vowel (see Section 2.1 below for more on durational variability).

In addition to the acoustic svarabhakti fragment, /rC/ clusters in Peninsular Spanish also exhibit articulatory characteristics that differ from those of other clusters, such as /lC/. Using the ElectroMagnetic Midsaggital Articulometry technique, Romero (1996) shows that Castilian Spanish [ld] exhibits gestural overlap and blending, while [rô] is articulated in sequential fashion. The two-dimensional displays in (2a,b) show tongue tip trajectories for the interdental fricative [ð], the dental stop [t], the alveolar lateral [l] and tap [ɾ], and the clusters [ld] and [rô].

(2) Tongue tip movement paths for intervocalic [l, ð, ld, t] in (a) and [ɾ, ð, rô, t] in (b), both in the context of vowel [o] (taken from Romero 1996: 105–6)

According to Articulatory Phonology, overlap between gestures involving the same articulator will produce a blending of gestural characteristics, which “shows itself in spatial changes in one or both of the overlapping gestures” (Browman and Goldstein 1990: 362). This prediction is confirmed by the tongue tip movement path for the [ld] cluster in (2a), whose single constriction is at a location intermediate between those of dental [t] and alveolar [l]. However, the movement path for the rhotic cluster in (2b) suggests a sequential articulation of gestures and does not show evidence of overlap or blending. In this cluster, the tongue tip begins at a location close to that of single [ɾ], then subsequently moves forward in a “sliding” motion to form a constriction at a point near that of spirantized [ð]. Therefore, /rd/
and /ld/ clusters in Castilian Spanish differ in gestural alignment – only the latter exhibits overlap and blending.

Romero hypothesizes that the exceptional articulation of /rd/ stems from the inherently short duration of the coronal tap [r]. According to the duration values for Spanish consonants provided by Navarro Tomás (1918), shown in (3), the average duration of [r] is about 25 ms, compared to approximately 65 ms for [l], and 72 ms for [d]:

\[
\begin{align*}
[r] & \ 25 \text{ ms} < [l] \ 65 \text{ ms} < [d] \ 72 \text{ ms}
\end{align*}
\]

The extreme brevity of the tap stems from a ballistic gesture whereby the tongue tip is thrown up against the alveolar ridge (Ladefoged 1993: 168). The tongue tip must be “cocked” back from neutral position to gain momentum for tapping, and it must move away quickly from the point of contact if extra-short constriction is to be achieved. Inouye (1995: 55–6) invokes the metaphor of throwing a baseball, which also involves a ballistic gesture with similar approach and release phases. The throw will be more effective if one’s arm is cocked back from rest position in order to gain momentum and if it is also allowed to follow through on its movement trajectory after the baseball is released. As in the case of throwing a ball, the ballistic tapping gesture is most effective when both the approach and release phases are properly executed.

The movement paths in (2b) clearly indicate both the approach and release phases of [r] when it occurs intervocically as well as preconsonantally. I propose that the sequential articulation of Castilian Spanish [rød] stems from the execution of the release phase of the rhotic, which separates the tap constriction from that of the following consonant, thereby ensuring an open transition between the two (see Catford 1977: 220). Furthermore, I assume that the svarabhakti fragment observed in (1) is the acoustic result of this transition, which allows some recovery of the underlying nuclear vowel (I return to this issue in Section 3).

Rhotics are known for the considerable phonetic variety they exhibit across languages, dialects, and speech styles. Although the same is true among Spanish varieties, most contemporary generative analyses tend to relegate dialectal phonetic variants to the realm of “low-level” phonetic detail. The following passage from Harris (1983: 62) is representative of the tendency to abstract away from the phonetic reality of rhotics:
There is an astonishing variety of \( r \)-quality phones in Spanish. A phonetics teacher from whom I took undergraduate courses in Mexico claimed to have identified over 40 types of \( r \) in the Valley of Mexico alone. Fascinating though this fact is, it leaves open the question of how the phonological system of Spanish works. … I thus reduce the vocabulary of symbols to just two, \([r]\) and \([r^1]\), which will be understood to jointly exhaust the rich phonetic variety … Of course, these are only the prototypical realizations. I will say little more about phonetic detail…

However, by not investigating rhotic variation, we might fail to recognize other systematic aspects in the cross-linguistic patterning of rhotics, which ultimately deserve some explanation.  

One such pattern comes from highland Ecuadorian Spanish (HES), in which rhotics may be realized phonetically as assibilated fricatives in casual speech. Assibilation occurs in many Latin American Spanish dialects but is acoustically more marked in the Andean highlands. Descriptive observations of HES, principally from Argüello (1978), show that the two rhotic phones are in complementary distribution in preconsonantal position in casual speech, with \([f]\) surfacing before homorganic (coronal) consonants and \([r]\) appearing elsewhere, as shown in (4). Following Argüello’s conventions, I employ \([\tilde{f}]\) to denote the devoicing of \([f]\) before voiceless consonants, as shown in (4b,d). For consistency, I continue to indicate svaraabhakti vowels as \([\tilde{a}]\) in (4a,g).

(4) a. \( \text{cuerpo} \) [\( \text{c} \tilde{e}^{\text{2}} \text{p} \)] ‘body’
   b. \( \text{puerta} \) [\( \text{c} \tilde{e}^{\text{1}} \text{t} \)] ‘door’
   c. \( \text{verde} \) [\( \text{c} \tilde{e} \text{d} \)] ‘green’
   d. \( \text{persona} \) [\( \text{c} \tilde{e}^{\text{2}} \text{s} \)] ‘person’
   e. \( \text{carne} \) [\( \text{a} \tilde{r} \text{n} \)] ‘meat’
   f. \( \text{perla} \) [\( \text{c} \tilde{r} \text{l} \)] ‘pearl’
   g. \( \text{garganta} \) [\( \text{a} \tilde{r}^{\text{3}} \text{y} \)] ‘throat’

The assibilated rhotic appears before a following homorganic consonant, with which it agrees in voicing, as in (4b–f). However, \([\tilde{f}]\) is unattested in coda position before heterorganic consonants, as in (4a,g).
In contrast to the Peninsular Spanish pattern shown in (1), /rC/ clusters exhibit an alternation between [r] and [f] in casual HES. The assibilated variant has the more limited distribution, appearing before coronal consonants, while [r] appears elsewhere, before labials and velars. Although this distribution is apparent in the transcribed data presented by Argüello (1978), shown in (4), no laboratory studies have been conducted to verify the claim that preconsonantal rhotics are realized as such in this Spanish variety. The following section presents descriptive evidence of coda assibilation through spectrographic analysis of /rC/ clusters.

2. Acoustic study of highland Ecuadorian Spanish clusters

For the present investigation, data were gathered from recordings of five speakers of HES, the dialect that formed the basis of Argüello’s (1978) study. Table 1 lists background information for the subjects:

<table>
<thead>
<tr>
<th>Subject</th>
<th>Gender</th>
<th>Place of origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>EM</td>
<td>Male</td>
<td>Imbabura</td>
</tr>
<tr>
<td>GB</td>
<td>Male</td>
<td>Tabacundo</td>
</tr>
<tr>
<td>MA</td>
<td>Female</td>
<td>Latacunga</td>
</tr>
<tr>
<td>JA</td>
<td>Male</td>
<td>Cuenca</td>
</tr>
<tr>
<td>JM</td>
<td>Male</td>
<td>Quito</td>
</tr>
</tbody>
</table>

All of the recorded subjects are native speakers of HES. The first four subjects in Table 1 read a short literary passage (see Appendix) and were recorded on reel-to-reel tape. The recordings were later digitized using audio editing software and stored in MPEG format at 22,050 Hz and 16-bit. The fifth subject was recorded directly to computer reading the same literary passage. All tokens of heterosyllabic /rC/ were extracted from the digitized recordings and were analyzed via waveform and spectrogram with version 1.5 of the SIL Speech Analyzer software.

Overall results indicate that for the five speakers consulted, coda /r/ generally surfaces as such in preconsonantal contexts, except before homorganic consonants, in which case assibilation may or may not apply. Given that assibilation in HES has been associated with casual speech (Argüello 1978), the variability of assibilation observed in the present study is not
surprising, since reading tasks tend to promote careful speech styles in laboratory settings. The following sections examine several representative tokens collected in the study, beginning with heterorganic clusters.

2.1 Svarabhakti in heterorganic /rC/

Realizations of coda /r/ before heterorganic consonants in HES are illustrated by the tokens *enorme* ‘enormous’ (subject GB) in Figure 1 and *cargados* ‘loaded’ (subject EM) in Figure 2:

*Figure 1. Svarabhakti in [r₃.m] cluster of *enorme* ‘enormous’, subject GB*
In both cases, [r] is phonetically separated from the following consonant by a svarabhakti vowel fragment, whose duration is approximately 24 ms for [r.m] versus 48 ms for [r.y]. Such variability is in agreement with what has previously been shown for Peninsular Spanish /rC/ clusters, in which the duration of svarabhakti typically reaches and frequently surpasses that of the tap constriction: “The duration of the intervening vocalic element is highly variable even in the same word repeated several times by the same individual. This variability probably stems from rate of speech and from the fact that speakers are unaware of the existence of this vowel fragment, even though in most cases it attains a duration greater than that of the r [my translation]” (Gili Gaya 1921: 279).

In sum, Figures 1 and 2 suggest that heterorganic /rC/ clusters in HES are realized the same as the Peninsular Spanish /rC/ clusters shown in (1), namely with an intervening open transition and concomitant vowel fragment of variable duration.
2.2 Variable assibilation in homorganic /rC/

As noted above, the data collected from the HES speakers show that coda /t/ exhibits variable assibilation before homorganic consonants. The two rhotics [ɾ] and [ɾʷ] vary freely in this position, whereas the latter phone is subject to devoicing before voiceless consonants. Figures 3 and 4 show the realizations of /t/ before homorganic /t/ in the tokens *huertas* ‘gardens’ (subject EM) and *partes* ‘parts’ (subject MA), respectively. In Figure 3, underlying /ɾt/ is realized with an intervening svarabhakti vowel of 32 ms in which some trace of formant structure is preserved from the nuclear vowel opposite the tap constriction. In Figure 4, coda /ɾt/ undergoes assibilation and partial devoicing before /t/. Observe that no svarabhakti vowel is present in the assibilated cluster. The assibilated rhotic corresponds to a 47 ms period of strident frication, whose turbulence is indicated by the presence of aperiodic energy in the upper spectra. This variant contrasts with the non-assibilated [ɾ] of Figure 3, which is 17 ms in duration and exhibits no turbulent noise. In sum, the clusters in Figures 3 and 4 differ in that [ɾʰ.t] exhibits an open transition and svarabhakti between the adjacent consonants, whereas [ɾʰ.t] does not.

![Figure 3](image-url)  
*Figure 3. Svarabhakti in [ɾʰ.t] cluster of *huertas* ‘gardens’, subject EM*
Finally, Figure 5 illustrates the assibilation of /t/ before homorganic /n/ in the token *terneros* ‘calves’ (subject GB). The rhotic in this cluster corresponds to a 52 ms period of turbulent frication, and no svarabhakti vowel is observed between [r] and the following consonant. Substantial voicing is maintained throughout the assibilated rhotic in [r.n], in contrast to the partial devoicing of [r] before [t] in Figure 4 above.
As an anonymous reviewer points out, there seems to be a compensatory lengthening effect associated with the asibilation of precoronal /r/. Comparing the sum duration of the tap and the svarabhakti vowel shown in Figure 3 (17 ms + 32 ms = 49 ms total) with that of the assibilated rhotics shown in Figure 4 (47 ms) and in Figure 5 (52 ms), one observes that the absence of svarabhakti entails a longer constriction period for the assibilated phone. I leave it to future research to verify this effect within a more controlled experimental design. However, supposing the same results were obtained in a controlled setting, the relatively longer duration of the assibilated phone may have a plausible aerodynamic explanation. Romero (1995) claims that fricatives must be longer than approximants to allow pressure to be built up at the place of constriction, thus generating turbulent airflow.³ While the presence of an open transition ensures a brief approximant articulation of the tap, the absence of the transition allows for a durational increase in the assibilated fricative. (See the discussion surrounding Figure 7 below.)
2.3 Summary

The representative spectrograms presented above reveal several properties of /rC/ clusters in HES based on the speech samples collected and analyzed in the present study:

<table>
<thead>
<tr>
<th>Heterorganic /rC/</th>
<th>Homorganic /rC/</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assibilation unattested</td>
<td>Variable assibilation</td>
</tr>
<tr>
<td>Extra-short rhotic constriction</td>
<td>Longer constriction of assibilated rhotic</td>
</tr>
<tr>
<td>Intervening svarabhakti vowel of variable duration</td>
<td>Assibilation and svarabhakti mutually exclusive</td>
</tr>
<tr>
<td></td>
<td>[ɾ] subject to partial devoicing</td>
</tr>
</tbody>
</table>

In the remainder of this paper, I illustrate a gestural approach to assibilation in HES clusters within the framework of Articulatory Phonology and then integrate the phonetic explanation into a constraint-based account of rhotic variation in Spanish /rC/ clusters.

3. The role of gestural timing in /rC/ cluster realization

Bradley (1999) proposes a gestural explanation of rhotic assibilation in HES. Specifically, it is argued that the tongue tip gestures for /r/ and an adjacent coronal consonant undergo overlap and blending in casual speech, thereby producing an overall tongue tip trajectory whose duration and constriction degree are sufficient for turbulent airflow. This idea is consistent with Browman and Goldstein’s model, in which greater overlap (and blending) yields casual speech forms that differ from their canonical realization in careful speech. In order to see how gestural blending is responsible for assibilation, we must first account for the realization of non-overlapped clusters that exhibit [ɾ] and concomitant svarabhakti. In Articulatory Phonology, consonantal gestures are superimposed on vocalic gestures, which are articulatorily adjacent (Gafos 1999). This explains why the svarabhakti fragment appearing in a [Vɾ⁹.C] sequence is always a continuation of the formant structure present in the nuclear vowel on the opposite side of the tap constriction. Both the full vowel and the vowel fragment stem from the
same tongue body gesture, and the superimposed tap constriction produces a brief interruption separating the two. Such an account concords with the definition of Spanish /ɾ/ proposed by Gili Gaya (1921: 279): “It is a vocalic sound interrupted by an alveolar contact that is voiced and more or less intense [my translation].”

Consider the timing relationship depicted in Figure 6 for the hypothetical [Vɾ⁰,tV] sequence. In this gestural representation, the activity of each relevant articulator is depicted on a separate tier. Boxes represent gestures, and the length of a box denotes the period of time during which the articulator is under active control. Gestures that overlap on the same articulatory tier are indicated by broken lines (e.g., the tongue body gestures for V1 and V2). When the tongue tip gesture for /ɾ/ is temporally separated from that of the following /t/, the overlapping tongue body gesture for V₁ is recovered as a svarabhakti vowel fragment. This timing relationship is hypothesized to be responsible for the HES cluster realizations shown in Figures 1 through 3, and more generally for all /ɾC/ clusters in Peninsular Spanish, as shown by the data in (1). The lack of significant gestural overlap between /ɾ/ and the following consonant allows for the successful execution of the tap’s release phase, which yields the sliding articulation documented by Romero (1996) in (2b).

\[
\begin{array}{cccc}
V₁ & r & t & V₂ \\
\hline
\text{TONGUE TIP} & & & \\
\text{TONGUE BODY} & & & \\
\text{GLOTTIS} & & & \\
\end{array}
\]

\[\text{Figure 6. Gestural representation of } [Vɾ⁰,tV] \]

On the other hand, no svarabhakti fragment can be recovered when the tongue tip gestures for /ɾ/ and the following homorganic consonant are overlapped, as in Figure 7. According to Browman and Goldstein (1990),
gestural overlap will yield different results depending on whether the two gestures are on the same or different articulatory tiers. The prediction is that same-tier overlap will produce a *blending* of the characteristics of the two gestures, which “shows itself in spatial changes in one or both of the overlapping gestures” (362). Overlap between the gestures associated with /ɾ/ and /t/ in Figure 7 blends the resulting articulatory trajectories, thereby removing the open articulatory transition between the two consonants, along with the svarabhakti vowel it normally produces. Without the open transition to ensure a brief constriction period, the duration of /ɾ/ is increased, yielding a fricative [ɾ]. In addition, overlap between the tongue tip gesture of /ɾ/ and the glottal spreading gesture of /t/ results in partial devoicing of the former.

\[
\begin{array}{ccc}
V_1 & \tilde{\eta} & t & V_2 \\
\end{array}
\]

![Gestural representation of [\(V\tilde{\eta}.tV]\)](image)

*Figure 7. Gestural representation of [\(V\tilde{\eta}.tV]\]*

The overlap scenario shown in Figure 7 presumably yields a tongue tip movement trajectory similar to that in (2a) for Castilian Spanish [\(ld\)]. Further articulatory investigation is required in order to determine whether overlap and blending produces a constriction location intermediate between alveolar [ɾ] and dental [t]. Nonetheless, an overlap account of [\(\tilde{\eta}.t\)] finds some support in the spectrographic results presented in Figure 4, in which svarabhakti is absent and laryngeal coarticulation yields partial devoicing of the rhotic. While the gestural account outlined above provides phonetic motivation for assimilation in homorganic /ɾC/ clusters, it remains unclear why [ɾ] is absent from heterorganic ones, as in Figures 1 and 2. Bradley
(1999) specifically argues that in HES, /r/ is “overlapped by adjacent consonantal gestures, with overlap resulting in gestural blending next to coronals [my emphasis]” (64). Such a general statement of gestural overlap turns out to be descriptively inadequate, since it predicts overlap between /r/ and any following consonant. What needs to be explained is why overlap obtains only in homorganic /rC/ clusters but not in heterorganic ones.

4. A phonetically-based Optimality-theoretic analysis

In this section, I develop a constraint-based account of the differences in gestural alignment between homorganic versus heterorganic /rC/ clusters in HES. Section 4.1 introduces the framework of Optimality Theory. Section 4.2 motivates the constraints necessary for the analysis of /rC/ clusters, which is then illustrated in Section 4.3.

4.1 Optimality Theory

Optimality Theory (OT; Prince and Smolensky 1993; McCarthy and Prince 1993a, 1993b) provides a framework for analysis in which ranked and violable constraints apply in parallel to determine the optimal mapping between input and output forms. This approach contrasts with derivational models in which ordered rules apply to yield a series of intermediate representations between input and output. In OT, two functions determine the optimal input-output mapping: GEN, which generates output candidates, and H-EVAL, which selects the output candidate which best satisfies the constraints. The structure of an OT grammar is shown in (5) (Prince and Smolensky 1993: 4):

\[(5) \quad \begin{align*}
\text{a.} & \quad \text{GEN (Input)}_k \rightarrow \{\text{Output}_1, \text{Output}_2, \ldots\} \\
\text{b.} & \quad \text{H-EVAL (Output)}_i, 1 \leq i \leq \infty \rightarrow \text{Output}_{\text{real}}
\end{align*}\]

Output candidates are evaluated in terms of their violations of the ranked constraints. Evaluations are shown in the form of a tableau:
Tableau 1. Evaluation of input-output mappings against constraints

<table>
<thead>
<tr>
<th>Input</th>
<th>CONSTRAINT A</th>
<th>CONSTRAINT B</th>
<th>CONSTRAINT C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output₁</td>
<td>*!</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Output₂</td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Output₃</td>
<td></td>
<td></td>
<td>**!</td>
</tr>
</tbody>
</table>

The input appears in the first cell of the tableau, while output candidates are shown below in the same column. Constraints are given along the top of the remaining columns. A crucial ranking between two constraints is indicated by a solid line separating the two columns. For example, Tableau 1 represents a language in which three hypothetical constraints are ranked as follows: CONSTRAINT A » CONSTRAINT B, CONSTRAINT C. That is, CONSTRAINT A outranks both CONSTRAINT B and CONSTRAINT C, but the latter two constraints are unranked with respect to one another. A constraint violation is indicated by an asterisk. If a violation causes an output candidate to be eliminated from the evaluation, then that violation is said to be fatal, and the symbol ‘!’ appears next to the relevant asterisk. The symbol ‘☞’ marks the winning output candidate (i.e., the candidate that remains after all others are eliminated).

As an illustration, let us consider the evaluation shown in Tableau 1. Output₁ violates CONSTRAINT A, which is top-ranked, as well as CONSTRAINT C. Since there are other candidates that do not violate CONSTRAINT A, Output₁ is immediately eliminated from consideration, and the lower-ranked constraints are now irrelevant to this candidate. None of the remaining candidates violates CONSTRAINT C, however, Output₂ incurs a single violation, while Output₃ incurs two violations. A candidate that multiply violates some constraint loses to any candidate that violates the same constraint to a lesser degree. The second violation of CONSTRAINT C by Output₃ is a fatal one, and Output₂ is selected as the winner.

To summarize, OT provides a framework in which phonological systems are expressed in terms of ranked and violable constraints. Grammars consist of “a set of highly general constraints which, through ranking, interact to produce the elaborate particularity of individual languages” (Prince and Smolensky 1993: 198). See Prince and Smolensky (1993) for a more detailed presentation of this formalism.
4.2 Constraints on gestural timing

Cho’s (1998a, 1998b) constraint-based account of Korean palatalization offers a means of evaluating gestural overlap in the Correspondence-theoretic version of OT (McCarthy and Prince 1995). In the present analysis, I assume that gestural timing relevant to /rC/ clusters is governed by the constraints in (6):

(6) a. IDENT(timing) (cf. Cho 1998a, 1998b)
   The temporal alignment of gestures in the input must be preserved in the output.

   Avoid faster-than-usual transitions between adjacent periods of greater stricture involving the same articulator.

Recall that in Articulatory Phonology, gestures function not only as units of articulation but also as the primitives of phonological organization. Gestures have internal duration and are temporally coordinated with each other in the phonological representation. IDENT(timing) in (6a) is a faithfulness constraint that seeks to preserve input timing relationships in the output. More specifically, this constraint enforces the requirement that input gestures be perceptually recoverable. With respect to /rC/ clusters, recoverability entails that the adjacent consonantal gestures be temporally coordinated in such a way as to ensure the presence of an intervening svarabhakti vowel (see Figure 6). The claim that svarabhakti favors the perceptual recovery of underlying /rC/ is reaffirmed in a recent cross-linguistic investigation by N. Hall (in progress). She argues that the presence of the vowel fragment gives the first consonant a stronger release and the second a stronger approach phase, thereby improving the perceptibility of both members of the cluster. Therefore, I assume that IDENT(timing) is satisfied by outputs such as [r^3,C], whereas like surface clusters exhibiting substantial gestural overlap violate this constraint. Furthermore, in subsequent tableaux, I include the svarabhakti vowel as part of the input in order to indicate that /r^3C/ clusters are characterized by non-overlap timing, as in Figure 6.10

In competition with faithfulness to input timing is the constraint *FAST/SAME in (6b), which encodes the articulatory markedness of an open transition between two homorganic consonants. The claim that open transitions are more marked between homorganic consonants than between
heterorganic ones is supported by consonantal transition phenomena in Sierra Popoluca, a Zoquean language spoken in Mexico (Elson 1947, 1956; Foster and Foster 1948). Consonant clusters in this language are realized with an intervening open transition if the consonants are heterorganic, while homorganic clusters lack such a transition, as shown in (7):

(7)  a. kekʰ.paʔ  ‘it flies’  min⁹(paʔ)  ‘he comes’
b. kek.gakʰ.paʔ  ‘it flies again’  ?añ.kiʔ  ‘yard’

In (7a), the open transition is realized as aspiration after the voiceless velar stop and as a short schwa-like vowel after the palatal nasal. The homorganic stop sequences [k.g] and [ŋ.k] in (7b) lack an open transition. I argue that *FAST/SAME is responsible for the absence of an open transition in homorganic stop clusters in Sierra Popoluca, as well as in homorganic /rC/ clusters in HES. This constraint is violated by outputs such as [C³.C], in which the adjacent consonants are homorganic (i.e., coronal in the case of /rC/ clusters in HES), whereas like surface clusters without an open transition satisfy this constraint.

It is important to define the notion of adjacency implied by the markedness constraint *FAST/SAME in (6b). Consider the syllabic representations of the hypothetical sequences shown in (8):

(8)  a. σ σ
     X X X X
     | | | |
     V r³ t V
     \---adjacent---

     b. σ σ σ
     X X X X X
     | | | |
     V r v t V
     \---non-adjacent---

In (8a), the consonants comprising the heterosyllabic [r³.t] cluster are adjacent on the timing tier, whereas [r] and [t] are non-adjacent in (8b) due to the presence of an intervening, lexically sponsored vowel. The syllabic status of the svarabhakti vowel differs from that of a full vowel in that the former does not function as a syllable nucleus. Rather, the fragment in (8a) is merely the acoustic result of an open transition between the adjacent consonants, as explained in Figure 6. On this view of adjacency, *FAST/SAME is violated by the presence of open transition between the
homorganic consonants in (8a), but the constraint is irrelevant in (8b) be-
cause the homorganic consonants are non-adjacent.

4.3 Analysis of /rC/ cluster realizations

Tableaux 2 and 3 illustrate the realizations of heterorganic and homorganic
/rC/ under the ranking IDENT(timing) » *FAST/SAME, which character-
izes Peninsular Spanish and careful speech in HES. In Tableau 2, [r.m] is a
narrow transcription intended to denote gestural overlap, in contrast to
[r^3.m], which exhibits an open transition and concomitant svarabhakti.11

<table>
<thead>
<tr>
<th>/r^3.m/</th>
<th>IDENT(timing)</th>
<th>*FAST/SAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. r^3.m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. r.m</td>
<td></td>
<td>*!</td>
</tr>
</tbody>
</table>

Tableau 2. Svarabhakti in heterorganic [r^3.m] cluster

<table>
<thead>
<tr>
<th>/r^3.t/</th>
<th>IDENT(timing)</th>
<th>*FAST/SAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. r^3.t</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>b. ū̃.t</td>
<td></td>
<td>*!</td>
</tr>
</tbody>
</table>

Tableau 3. Svarabhakti in homorganic [r^3.t] cluster

Faithfulness to input timing rules out the (b) candidates, thereby ensuring
that both the input clusters /r^3.m/ and /r^3.t/ are realized with an open transi-
tion and the associated svarabhakti vowel. The [r^3.t] cluster in candidate (a)
of Tableau 3 violates *FAST/SAME due to the presence of an open transi-
tion between two homorganic consonants, but the violation is tolerated un-
der duress of higher ranking IDENT(timing).

Recall the difference between Castilian Spanish [l.d] and [r^3. ũ̃] shown in (2), as observed by Romero (1996). I assume that the former clus-
ter lacks an open transition because the lateral liquid has a longer duration
and, therefore, does not possess the same articulatory release phase to en-
sure a brief constriction as does the rhotic (see the discussion surrounding
(3) in Section 1). As shown in Tableau 4, high-ranking IDENT(timing) fa-
vors [l.d] over the hypothetical candidate [l^3. ũ̃] because the addition of an
open transition constitutes an unfaithful realization of the gestural timing
relation specified for input /ld/. (Note: I assume that spirantization of /d/ is the result of other constraints not shown in the tableau).

<table>
<thead>
<tr>
<th>/ld/</th>
<th>IDENT(timing)</th>
<th>*FAST/SAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.  l̃d̃</td>
<td>*!</td>
<td>*</td>
</tr>
<tr>
<td>b.  l.d</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Tableau 4. Overlap in homorganic [l.d] cluster*

Since the tap contains an inherent release phase to ensure an extra-short constriction period, IDENT(timing) favors the preservation of the open transition and concomitant svarabhakti vowel in *Tableau 5:*

<table>
<thead>
<tr>
<th>/r^2d/</th>
<th>IDENT(timing)</th>
<th>*FAST/SAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.    r̃d̃</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>b.    řd̃</td>
<td></td>
<td>!</td>
</tr>
</tbody>
</table>

*Tableau 5. Svarabhakti in homorganic [r^2d] cluster*

Tableaux 6 and 7 show the effects of the opposite constraint ranking on the realization of input /r^2C/ in casual HES:

<table>
<thead>
<tr>
<th>/r^2m/</th>
<th>*FAST/SAME</th>
<th>IDENT(timing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.     r̃m</td>
<td></td>
<td>*!</td>
</tr>
<tr>
<td>b.     řm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Tableau 6. Svarabhakti in heterorganic [r^2m] cluster*

<table>
<thead>
<tr>
<th>/r^2t/</th>
<th>*FAST/SAME</th>
<th>IDENT(timing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.     r̃t</td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td>b.     řt</td>
<td></td>
<td>*</td>
</tr>
</tbody>
</table>

*Tableau 7. Assibilation in homorganic [řt] cluster*

On the assumption that markedness constraints are promoted in casual speech styles, the violation of *FAST/SAME by candidate (a) in *Tableau 7* now becomes fatal. As a result, input /r^2t/ maps to output candidate (b) in
which gestural overlap and blending yield assimilation and devoicing in the manner shown in Figure 7. Since *FAST/SAME is irrelevant in the case of heterorganic /r^m/, lower-ranked IDENT(timing) decides in favor candidate (a) in Tableau 6, just as it does under the opposite constraint ranking in Tableau 2.

5. Conclusion

While assimilation of rhotics is a common property of many Latin American Spanish dialects, Colantoni’s (2001) empirical investigation of Argentine varieties reveals that /r/ fails to surface as [f] in syllable codas. Moreover, Colantoni questions Argüello’s (1978) descriptive observations regarding coda /r/ assimilation in HES. The present study has provided further empirical support for the Ecuadorian pattern via spectrographic analysis of relevant tokens gathered from HES speakers. A gestural account was proposed in which the phonetic realization of /rC/ clusters stems from the ranking of two conflicting constraints, one which requires input clusters to be perceptually recoverable in the output, and another which encodes the articulatory preference for overlap between adjacent consonantal gestures involving the same articulator. By incorporating the notion of gestural alignment within a constraint-based approach, the analysis put forth here captures the phonetic motivation of rhotic assimilation in Spanish codas, as well as the systematic differences in /rC/ cluster realization across dialects and speech styles.

Appendix: Text employed in data elicitation

Cuando yo era niño, iba todos los años a pasar uno de los meses de vacaciones a casa de mi tío. La hacienda y sus dependencias abarcaban un terreno muy extenso. Estaban rodeadas de un enorme patio. Solía ayudar a mi tío y a sus empleados cuando podía, aunque probablemente no les ayudaba tanto como yo creía. En las cuadras tenía mi tío seis o siete caballos y algunas yeguas. Pero ahora, porque vive todavía, los ha sustituido por tractores y por una camioneta. En los establos tenía magníficos bueyes. Recuerdo como si fuera ayer cuando los vi por primera vez. También había vacas con sus terneros, así como cabras, ovejas y corderos. Menos pintorescos, pero de igual utilidad, eran los cerdos que vivían en sus pocilgas, y los gallos y las gallinas que tenían lo que a mí me parecía entonces un inmenso galline-
ro. Para un niño que pasaba once meses del año en una gran población, constituyen una novedad los pavos, los patos y los gansos que en otras partes no encontraba sino muertos y preparados para la mesa en la cocina. Uno de los encantos de aquellas visitas era la abundancia de frutas que comía yo en gran cantidad. Generalmente, las fresas y las frambuesas habían pasado ya, pero nos quedaban grosellas y cerezas. Y los manzanos, perales y ciruelos estaban cargados de fruta madura, hermosa y suculenta. ¿Cuáles son las diferentes partes de la hacienda? La casa, el patio, las dependencias y los campos que rodean la casa. ¿De qué constan las dependencias? Constán de las cuadras, los establos, los rediles, las pocilgas y los gallineros. ¿Cuál es, según Ud., el más útil de los animales domésticos? Yo creo que la vaca, no sólo porque da leche, sino porque la leche se transforma en mantequilla y en queso. Y además, la carne de vaca es una parte muy importante en nuestras comidas diarias. ¿No tenía su tío de Ud. abejas? No, Señor. Cuando se instaló en su hacienda hace treinta años, compró una gran cantidad de abejas. Pero la miel le daba tan poco que las vendió. ¿Tenía grandes huertas? No, nada más que una que estaba detrás de la casa. Pero era muy productiva, y daba cada año gran cantidad de frutas y legumbres. Pruebe Ud. una manzana. O, ¿prefiere Ud. ciruelas? Aquí las hay verdes si le gustan más que las maduras. Están muy dulces, gracias. Voy a tomar una de estas manzanas. Las peras y las manzanas son las frutas que más me gustan.

Notes

* This paper is the ongoing extension of research originally undertaken with Erin O’Rourke at the Pennsylvania State University in 1998, with much constructive criticism on the initial stages provided by Holly Nibert. The field recordings utilized in the present study come from a larger corpus of Spanish dialectal data made available by John Dalbor and digitized under the supervision of Eric Bakovic. Results of this ongoing research were presented by the present author at the Laboratory Approaches to Spanish Phonology conference, held September 6-7, 2002, at the University of Minnesota, Minneapolis. I wish to thank the audience members for helpful feedback and discussion, in particular David Eddington, Robert Hammond, José Ignacio Hualde, Anthony Lewis, Geoffrey Stewart Morrison, Pilar Prieto, and Erik Willis. Thanks also to an anonymous reviewer for comments and suggestions on a previous version of this paper. I alone am responsible for any remaining shortcomings.
1 Assibilation is also frequent in /tr/ clusters in Argentine and highland Ecuadorian varieties. For present purposes, I focus specifically on the realizations of preconsonantal /r/.

2 Spanish /rC/ clusters are overwhelmingly heterosyllabic, except for a few words in which /s/ is parsed along with /r/ in the preceding syllable rhyme, e.g., pers.pi.ca ‘perspicacious’ and pers.pe.c.ti.va ‘perspective’. See Harris (1983) for a discussion of Spanish syllabification.

3 Romero does not indicate the svarabhakti fragment in phonetic transcription. Given the discussion surrounding (1), however, [ɾɔ] is more appropriately transcribed as [ɾɔ̞].

4 Recasens (2001) observes a similar sliding movement in the same clusters in Catalan: “rd does not yield blending but C1-to-C2 sliding in view of the mobility of the tongue tip” (299).

5 Recent investigations have begun to redress the lack of attention given to phonetic detail (e.g., Blecua 2001; Bradley and Schmeiser 2003; Colantoni 2001, Hammond 1999, 2000; and Willis and Pedrosa 1998).

6 Coda liquids in Spanish are subject to a variety of other processes depending on the dialect, such as gliding, assimilation, retroflexion, and neutralization. The present study focuses specifically on the assibilation of preconsonantal /r/ in HES, but see Lipski (1994) for a comprehensive overview of phonological and phonetic variation across dialects.

7 John Lipski (personal communication) points out that in other dialects, fricative rhotics may appear before any consonant regardless of the homorganicity of the cluster (e.g., Mexican Spanish [la ʃiʃ.xen] la Virgen ‘the Virgin’). However, Fanny Argüello (personal communication) maintains the original observation of Argüello (1978) that assibilation in HES affects coda /ɾ/ only before coronals. Furthermore, none of the instances of coda /ɾ/ analyzed in the present study showed assibilation in heterorganic clusters.
Recasens (1991) observes via electropalatographic measurements involving Catalan speakers that closure for the tap is seldom complete, as expected from the momentariness of the apical gesture, which suggests that the tap is an approximant. Similarly, Bakovic (1994) argues that the tap is an approximant in Spanish.

A similar gestural explanation is proposed by Steriade (1990) and more recently Bradley (2001, 2002) and Hall (in progress).

The inclusion of non-contrastive phonetic detail, such as gestural timing, in input representations raises important questions concerning the relationship between phonetics and phonology in the grammar. An adequate treatment of this issue is beyond the scope of the present paper, but see Bradley and Schmeiser (2003) for further discussion.

Perhaps a more appropriate interpretation is that overlap in heterorganic /rC/ results in perceptual masking of the rhotic. Browman and Goldstein (1990: 361) cite the apparent deletion of English final /t/ in the casual speech form [masbi] versus the canonical form [mast#bi] must be. Articulatory measurements via X-ray pellet trajectories indicate that the tongue tip gesture for /t/ is still present in the casual speech form, although its acoustic effects are hidden due to overlap with the following bilabial gesture. See Bradley (2002) for a similar gestural account of rhotic deletion from heterorganic /rC/ clusters in Urban East Norwegian.

References


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