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Comments welcome!

Gestural Timing and the Resolution of /Cɾ/ Clusters in Romance*

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0. ***Introduction***

This paper considers the phonetic and phonological behavior of tautosyllabic obstruent-plus-apicoalveolar tap clusters in Romance varieties. It has long been noted that Spanish /Cɾ/ onsets exhibit an intervening vowel fragment (aka. *svarabhakti*, Whitney 1889) between the consonant and the adjacent rhotic (Gili Gaya 1921, Lenz 1892, Navarro Tomás 1918). The data in (1) from Malmberg (1965:31-7) illustrate svarabhakti in Spanish /Cɾ/. Although represented simply as [ᵊ] 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 1993:337-32).

(1)	*pronto*	[pᵊɾ]	'soon'	*otro*	[t̪ᵊɾ]	'other'
	fresco	[fᵊɾ]	'cool, fresh'	*negro*	[ɣᵊɾ]	'black'

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. Indeed, diachronic evidence points to the not infrequent development of an anaptyctic vowel in Romance /Cɾ/ clusters, which suggests that svarabhakti is a widespread phenomenon extending beyond Spanish.[1] The data in (2a) and the epigraphic evidence in (2b) and (2c) demonstrate cases of anaptyxis in Spanish (Quilis 1988:300), Late Latin and Sardinian (Steriade 1990:390), respectively, in which the quality of the epenthetic vowel matches that of the underlying nucleus tautosyllabic with the complex onset.[2] (Note: periods denote syllable boundaries.)

(2)	a.	*co.ró.ni.ca*	< *cró.ni.ca*	'chronicle'
		tí.gue.re	< *ti.gre*	'tiger'
		ta.ra.bi.lla	< *tra.bi.lla*	'stirrup'
	b.	*Mi.ta.ra*	< *Mi.tra*	(no glosses provided)
		sci.rip.tum	< *scrip.tum*	
	c.	*um.ba.ra*	< *um.bra*	
		co.lo.vu.ru	< *co.lo.bru*	

As Malmberg (1965:38) argues, svarabhakti and anaptyxis may be seen as constituting one end of a continuum of /Cɾ/ realizations. Near the opposite end are cases of phonetic merger, attested in limited areas of Spain and more extensively in Latin America. The data in (3) illustrate the merger of /Cɾ/ clusters (Alonso 1925:179-89):[3]

(3)	*apretar*	[pɹ̥]	'to squeeze'
	otro	[tɹ̥]	'other'
	vendrá	[dɹ]	's/he will come'
	escribir	[kɹ̥]	'to write'
	magras	[ɣɹ]	'lean (fem. pl.)'

In contrast to the non-merged clusters in (1), merger entails frication of the rhotic, as well as the loss of both the intervening svarabhakti fragment and the extra-short constriction period of apicoalveolar [ɾ]. In addition, merger exhibits assimilatory behavior depending on the consonants involved. The rhotic is progressively devoiced after voiceless consonants (e.g., [kɹ̥] versus [ɣɹ]), and dental /t̪/ and /d̪/ assimilate regressively to the rhotic, yielding an alveolar quasi-affricate realization (e.g., [tɹ̥] versus [t̪ᵊɾ]).[4]

Finally, the Portuguese of southeastern Brazil constitutes the extreme case in which /Cɾ/ onsets may undergo complete reduction to the first consonant of the cluster (John Harris 1997:363; see also Cristófaro-Silva 2000):

(4)	a.	*pratinho*	[pa.ˈtʃi.ɲu]	'small plate'
		livro	[ˈli.vu]	'book'
	b.	*prato*	[ˈpᵊɾa.tu]	'plate'
		livreto	[li.ˈvᵊɾe.tu]	'booklet'

The examples in (4a) show that underlying /ɾ/ is deleted from complex onsets in unstressed syllables. A comparison with the morphologically related forms in (4b) shows that /Cɾ/ onsets do not undergo reduction in stressed syllables.[5]

The generalization emerging from these data is that Romance /Cɾ/ clusters are realized along an intersegmental duration continuum as a function of the relative phonetic separation between the consonants of the cluster. Figure 1 illustrates the range of realizations for underlying /CɾV/:

Figure 1: *Continuum of intersegmental duration for realizations of* /Cɾ/

In this paper, I argue that the phonetic continuum in Figure 1 derives from the relative timing of the articulatory gestures associated with each member of the /Cɾ/ cluster. A formal account is developed, couched within Optimality Theory (OT; Prince & Smolensky 1993, McCarthy & Prince 1995), in which phonetic constraints on intergestural timing interact directly with phonological constraints against segment deletion. Ranking permutation of the proposed constraints yields a factorial typology capable of generating the attested cluster realizations.

1. *The role of gestural timing in* /Cɾ/ *cluster realization*

Articulatory Phonology (Browman & Goldstein 1989, 1990, 1991, 1992) provides a framework within which to examine issues of gestural timing. In this model, gestures are dynamically defined articulatory movements that produce a constriction in the vocal tract. Three aspects of the gestural model are relevant for an analysis of /Cɾ/ clusters in Romance. First, articulatory gestures have internal duration, a property represented abstractly in terms of a 360° cycle. Phonetic timing is thus intrinsic to the phonological representation, and gestures are phonological primitives as well as units of articulation. 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. Second, adjacent gestures are temporally coordinated with respect to each other and may exhibit varying degrees of overlap. Finally, consonantal articulations are superimposed on vocalic gestures, which are themselves articulatorily adjacent (Gafos 1999).

Following Cho (1998b:35), I assume that throughout the course of first language acquisition, learners construct a permissible range of overlap between adjacent gestures and that this range is encoded in lexical entries in terms of a Phase Window (Byrd 1994, 1996). Figure 2 illustrates three hypothesized patterns of gestural overlap between adjacent /C/ and /ɾ/. (Note: The dotted lines delineate the lexically specified Phase Window.)

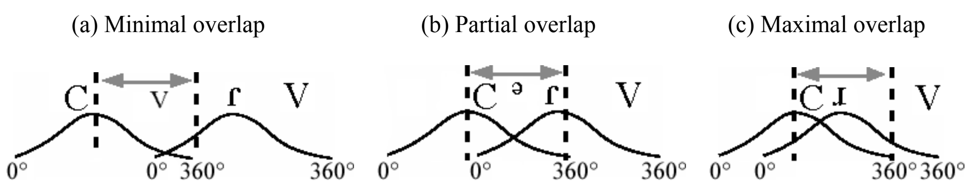


Figure 2: *Three patterns of overlap between adjacent gestures for* /C/ *and* /ɾ/

While minimal overlap in (a) permits a greater recovery of the overlapping vowel gesture (not shown in the diagrams), partial overlap in (b) yields only a reduced vowel fragment. On the other hand, maximal overlap in (c) shifts the 0° onset of the /ɾ/-gesture outside the Phase Window, which precludes the svarabhakti fragment and results in merger of the /Cɾ/ sequence.

The timing-based account in Figure 2 provides a phonetic explanation for the realizations of /Cɾ/ clusters described in (1)–(3) above. First, variability in the duration of svarabhakti, as observed by Gili Gaya (1921) and Malmberg (1965), stems from the variable timing of the gestures for

Malmberg (1965), stems from the variable timing of the gestures for /C/ and /ɾ/ during speech production. The minimal and partial overlap scenarios in Figure 2 actually comprise a continuous range of intermediate degrees at which the /ɾ/-gesture may be timed with respect to the /C/-gesture. Second, the fact that consonantal gestures are superimposed on vocalic gestures explains why svarabhakti is always a continuation of the formant structure present on the opposite side of the tap constriction. Both the nuclear vowel and the svarabhakti fragment stem from the same vocalic gesture, and the superimposed tapping gesture produces a brief interruption separating the two.[6] The same explanation holds in the case of diachronic anaptyxis. Over time, listeners plausibly misinterpret certain longer svarabhakti fragments as full vowels and restructure their phonological representations accordingly for the relevant lexical items. (See the discussion surrounding Figure 6 below.)

Finally, the assimilatory behavior observed in merger receives a straightforward explanation as the effects of gestural overlap. According to Browman & Goldstein (1990), gestures in casual speech are expected "to show decreased magnitudes (in both space and time) and to show increasing temporal overlap" (p. 360). Many types of casual speech alternations, such as deletions, assimilations, and weakenings, can be seen as the consequences of gestural reduction and overlap. On this view, the assimilations observed in merger plausibly result from maximal overlap, as illustrated in Figure 3.

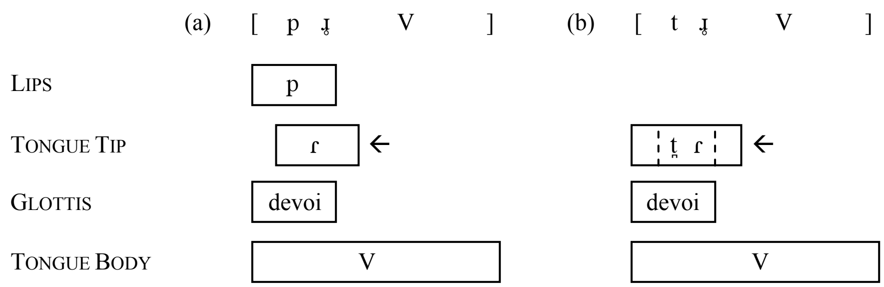


Figure 3: *Maximal overlap yields merger in* [pɹ̥] *(a) and* [tɹ̥] *(b) clusters*

In the above gestural representation, the activity of each relevant articulator is depicted on a separate tier, whose labels appear on the left. Boxes represent gestures, and the length of a box denotes the period of time during which the articulator is under active control. The arrow indicates that the tongue tip gesture for /ɾ/ has shifted leftward such that it coincides temporally with preceding gestures. Dotted lines denote overlap on the same tier.

Consider first the progressive devoicing of the rhotic. In Figure 3, coordination of the glottal devoicing gesture with the bilabial and dental closure gestures is responsible for the voicelessness of [p] and [t̪], respectively. Alonso's (1927) meticulous description of the articulation of such clusters is particularly insightful: "La *r* tiende a formarse durante la articulación de la oclusiva sorda anterior, invadiendo su explosión, dejándose a su vez invadir por la sordez de esa explosión … El esmero o el forzar la voz hacen recobrar personalidad a los sonidos" (186-7).[7] In gestural terms, rhotic devoicing stems from greater overlap between the tongue tip gesture for /ɾ/ and the glottal devoicing gesture of the preceding consonant. The fact that overlap-induced devoicing is limited to casual speech lends support to the gestural explanation, given that casual speech is characterized by greater overlap.

With respect to clusters in which the initial consonant is an underlying dental stop, merger with the following rhotic results in an alveolar quasi-affricate [tɹ̥]. Commenting on the cross-linguistic nature of this type of assimilation, Malmberg (1965) observes that the resultant articulation is actually intermediate between dental and alveolar: "Esta tendencia de la consonante *r* a combinarse con una dental … para formar una nueva consonante, *que es generalmente un término medio entre las dos* [my emphasis], no es desconocida en otras lenguas" (p. 39).[8] In the gestural model, overlap between adjacent gestures engaging the same articulator will produce *blending* of the characteristics of the two gestures, which "shows itself in spatial changes in one or both of the overlapping gestures" (Browman & Goldstein 1990:362). The retraction of dental stops when merged with a following apicoalveolar /ɾ/ plausibly reflects a compromise between the lexically specified constriction locations of the adjacent tongue tip gestures, as shown in Figure 3b.

The spectrograms in Figure 4 and Figure 5 illustrate svarabhakti and merger in [t̪ᵊɾ] and [pɹ̥] clusters in contemporary Spanish, respectively.[9]

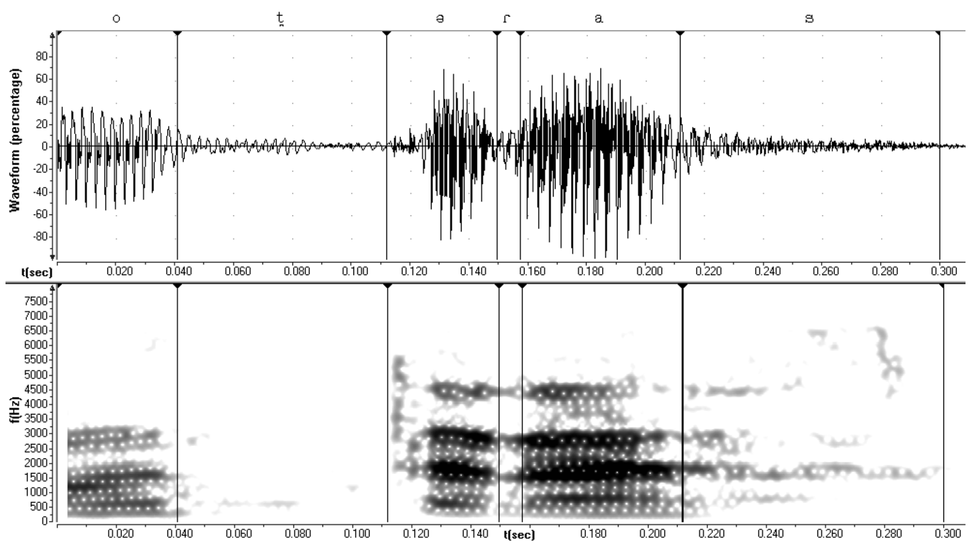


Figure 4: *Spanish* otras *'others' illustrating svarabhakti vowel fragment of* [t̪ᵊɾ] *cluster*

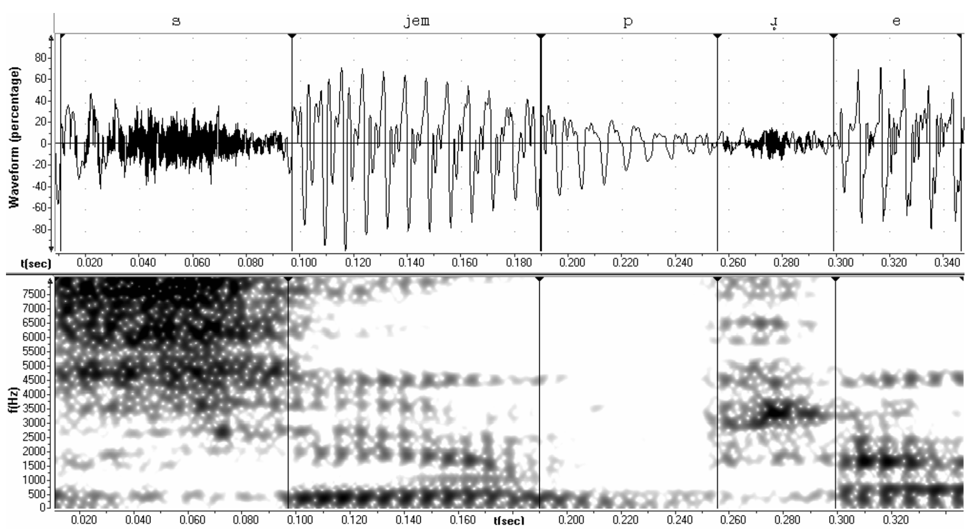


Figure 5: *Spanish* siempre *'always' illustrating merger of* [pɹ̥] *cluster*

In Figure 4, minimal overlap of the gestures for /t̪/ and /ɾ/ permits recovery of the underlying nuclear vowel as a svarabhakti fragment of 38 ms in duration, with an intervening tap constriction of 8 ms. In Figure 5, the rhotic corresponds to a 43 ms period of voiceless frication, which presumably results from substantial overlap of the /ɾ/-gesture with the glottal devoicing gesture of the preceding /p/, as shown in Figure 3a. In sum, the spectrographic evidence presented above illustrates the acoustic effects of the gestural timing relationships that are hypothesized to be responsible for svarabhakti and merger in /Cɾ/ clusters.

2. *A phonetically-based Optimality-theoretic analysis of Romance* /Cɾ/

Cho's (1998a,b) constraint-based analysis of Korean palatalization offers a means of evaluating gestural overlap in the Correspondence-theoretic version of OT (McCarthy and Prince 1995). In the remainder of this paper, I motivate an analysis in which phonetic timing constraints interact directly with phonological constraints against segment deletion to generate the patterns of /Cɾ/ realizations attested across Romance varieties.

2.1 *Proposed constraints and rankings*

In the present analysis, I assume that intergestural timing relevant to /Cɾ/ clusters is governed by the constraints in (5):[10]

(5) a. IDENT(timing) (based on Cho 1998a,b)

The relative timing of gestures in the output must fall within the lexically specified Phase Window, which determines a permissible range of gestural overlap.

b. OVERLAP (based on Cho 1998a,b)

Adjacent consonantal gestures must be maximally overlapped.

As shown in Tableau 1, the faithfulness constraint IDENT(timing) in (5a) bans any output timing relationship in which the 0° onset of the /ɾ/-gesture falls outside the lexically specified Phase Window.

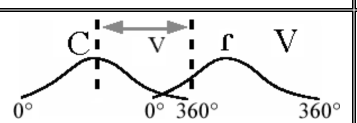
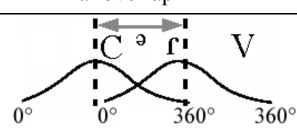
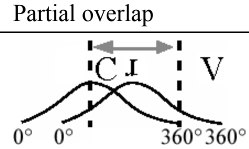
	IDENT(timing)
 ☞ Minimal overlap	
 ☞ Partial overlap	
 Maximal overlap	*!

Tableau 1: *Variable duration of svarabhakti vowel fragment*

Given that phonetic timing is a continuous dimension, the optimal candidates in Tableau 1 should be interpreted as abstractions denoting a range of intermediate degrees of gestural overlap. Therefore, IDENT(timing) will permit a certain amount of variability as long as the timing relation falls within the lexically specified Phase Window. This variability in turn governs the duration of the intervening svarabhakti vowel fragment.

OVERLAP in (5b) is a markedness constraint that prefers maximal coarticulation between adjacent consonantal gestures, as shown in Tableau 2.

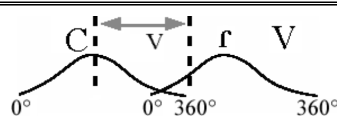
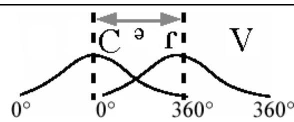
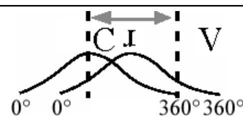
	OVERLAP
 Minimal overlap	*!
 Partial overlap	*!
 ☞ Maximal overlap	

Tableau 2: *Merger stems from maximal overlap*

In the case of /Cɾ/ clusters, OVERLAP is responsible for merger and the concomitant assimilatory effects associated with maximal overlap, as illustrated by the gestural representations shown in Figure 3 above.[11]

Faithfulness to input timing in (5a) conflicts with the articulatory imperative in (5b) that adjacent consonantal gestures should be maximally overlapped, such that the higher ranking constraint determines the gestural timing relationship of /Cɾ/ clusters in the output. Another way to satisfy both constraints is through cluster reduction, which occurs in unstressed syllables in southeastern Brazilian Portuguese, as shown in (4) above. Now, if reduction entails loss of the gesture associated with /ɾ/, then both IDENT(timing) and OVERLAP are vacuously satisfied because the output no longer contains two adjacent consonantal gestures. However, deletion violates MAX-IO in (6) because it involves a segment in the input that lacks an output correspondent:[12]

(6) MAX-IO (cf. McCarthy & Prince 1995)

Input segments have correspondents in the output.

As long as MAX-IO is dominant, underlying /ɾ/ surfaces faithfully, and the relative timing of its associated gesture with respect to the that of the preceding consonant depends on the ranking of IDENT(timing) and OVERLAP. Given an input /Cɾ/ cluster, then, the rankings shown in (7) produce svarabhakti (and potential anaptyxis) (a), merger (b), and reduction (c):

(7) Factorial typology

a. Svarabhakti: IDENT(timing), MAX-IO » OVERLAP

b. Merger: OVERLAP, MAX-IO » IDENT(timing)

c. Reduction: IDENT(timing), OVERLAP » MAX-IO

The remainder of this section illustrates the rankings in (7a,b). Section 3 argues that (7c) requires additional prosodic faithfulness constraints in order to account for the role of stress in Brazilian Portuguese reduction.

2.2 *Svarabhakti and anaptyxis*

As Tableau 3 demonstrates, the ranking IDENT(timing), MAX-IO » OVERLAP in (7a) permits a range of gestural overlap in accordance with the lexically specified Phase Window for /Cɾ/ clusters. Minimal overlap in candidate (a) produces a svarabhakti fragment approximating the duration of an unstressed vowel, while partial overlap in (b) yields a shorter fragment.

		/fresko/	IDENT(timing)	MAX-IO	OVERLAP
☞	a.	feres.ko			*
☞	b.	f^əres.ko			*
	c.	fɹ̥es.ko	*!		
	d.	fes.ko		*!	

Tableau 3: *Svarabhakti of variable duration in Spanish* fresco *'cool, fresh'*

Although minimal overlap in candidate (a) of Tableau 3 creates the appearance of two vowels, I assume that the longer vowel fragment does not create a new syllable. In an extensive cross-linguistic survey of svarabhakti phenomena, N. Hall (in progress) observes that svarabhakti vowels are *metrically cohesive* with the adjacent full vowel whose quality they copy. That is, languages tend to count svarabhakti and the original vowel as one for stress purposes. An example from Spanish suffices to illustrate this point:

(8) *hydrómetro* [i.ðɾó.me.t̪oɾo] 'hydrometer'

*[i.ðɾó.me.t̪o.ɾo]

In Spanish, main stress is confined without exception to a three-syllable window at the right edge of the morphological word (James Harris 1995:869). If the svarabhakti fragment surfacing in the final /t̪ɾ/ cluster in (8) were to create a new syllable, then stress would fall outside the three-syllable window yielding ungrammatical results. This evidence suggests that svarabhakti is not the result of a synchronic process of vowel epenthesis. On this view, the anaptyctic vowels in (2) are more appropriately analyzed as occasional historical developments whereby longer svarabhakti fragments are phonologically reinterpreted over time as full lexical vowels, as illustrated in Figure 6 for the hypothetical sequence /t̪ɾa/. Once phonological restructuring has taken place as in Figure 6b, the Phase Window of permissible gestural overlap for /t̪/ and /ɾ/ is dissolved because the anaptyctic vowel has broken up the onset cluster and the associated consonantal gestures are no longer adjacent.

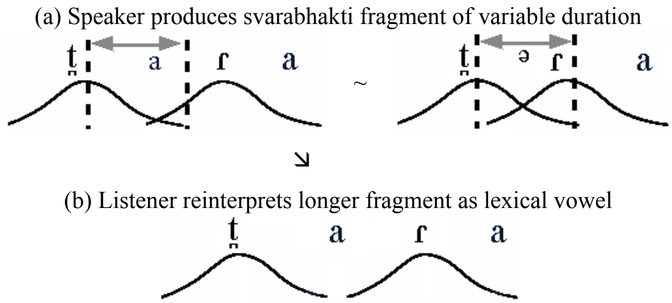


Figure 6: *Before (a) and after (b) diachronic anaptyxis:* /t̪ɾa/ > /t̪aɾa/

Crucial to the above explanation is the notion of *gestural misparsing*, whereby language learners erroneously interpret certain aspects of the acoustic signal to be the result of intentional articulatory gestures on the part of the speaker. Browman & Goldstein (1991:331-3) observe that changes which arise from misparsing "do not involve adding articulations that were not there to begin with; rather they involve changes in the parameters of gestures that are already present." In Figure 4, the svarabhakti fragments in (a) and the anaptyctic vowel in (b) all stem from the same overlapping vowel gesture, and the misparsing that occurs in (b) involves a change in the relative timing of adjacent consonantal gestures.

2.3 *Merger*

The ranking OVERLAP, MAX-IO » IDENT(timing) in (7b) optimizes maximal overlap between the adjacent consonantal gestures of /Cɾ/ clusters. Tableau 4 demonstrates how this ranking produces merger of Spanish /t̪ɾ/, with concomitant mutual assimilation in voicing and place (see the discussion surrounding Figure 3 above).

	/ot̪ɾo/	OVERLAP	MAX-IO	IDENT(timing)
a.	o.t̪oɾo	*!		
b.	o.t̪ᵊɾo	*!		
☞ c.	o.tɹ̥o			*
d.	o.t̪o		*!	

Tableau 4: *Merger in Spanish* otro *'other'*

Recall Alonso's (1927:186-7) observation that merger of Spanish /Cɾ/ is characteristic of casual speech, while in careful speech the perceptual integrity of the cluster is preserved. These stylistic variation effects follow straightforwardly in the constraint-based account proposed here. The ranking OVERLAP » IDENT(timing) reflects the preference for maximal overlap and consequent merger in casual speech, as shown in Tableau 4. However, when faithfulness to input timing outranks OVERLAP in careful speech, as illustrated above in Tableau 3, perceptually optimal timing is enforced via the lexically specified Phase Window for /Cɾ/ clusters.

3. ***Reduction and prosodic faithfulness in Brazilian Portuguese***

The final pattern to account for is that of southeastern Brazilian Portuguese. As demonstrated by the alternations in (4), /Cɾ/ clusters reduce to the initial consonant in unstressed syllables but surface faithfully under stress. As it currently stands, the ranking IDENT(timing), OVERLAP » MAX-IO given in (7c) actually makes the wrong predictions, as shown in Tableau 5. (Note: The 💣 symbols denote incorrectly chosen candidates).

		/livɾetu/	IDENT(timing)	OVERLAP	MAX-IO
	a.	li.ˈveɾe.tu		*!	
	b.	li.ˈvᵊɾe.tu		*!	
	c.	li.ˈvɹe.tu	*!		
💣	d.	li.ˈve.tu			*
💣	e.	li.ˈɾe.tu			*

Tableau 5: *Deletion predicted under stress in Brazilian Portuguese* livreto *'booklet'*

Specifically, low-ranked MAX-IO is incapable of ruling out the deletion of either consonant in a stressed syllable.

To overcome this problem, I adopt the general prosodic faithfulness constraint MAXHEAD-IO as proposed by Goad & Rose (to appear), shown in (9). On the assumption that inputs are fully prosodified, this constraint ensures that input segments occupying the head of a constituent are realized faithfully in the output.[13]

(9) MAXHEAD(PCat)-IO (from Goad & Rose, to appear)

Every segment prosodified in the head of some prosodic category in the input has a correspondent in the head of that prosodic category in the output. PCat ∈ {Onset, Nucleus, Rhyme, σ, Foot…}

Two instantiations of MAXHEAD-IO are necessary to capture the Brazilian Portuguese pattern. First, MAXHEAD(FOOT)-IO prohibits the deletion of segments from stressed syllables, as shown in Tableau 6. (Note: Parentheses mark the edges of feet.)

		li(ˈvɾe.tu)	MAXHD(FT)-IO	IDENT(timing)	OVERLAP	MAX-IO
☞	a.	li(ˈveɾe.tu)			*	
☞	b.	li(ˈvᵊɾe.tu)			*	
	c.	li(ˈvɹe.tu)		*!		
	d.	li(ˈve.tu)	*!			*
	e.	li(ˈɾe.tu)	*!			*

Tableau 6: *Deletion blocked under stress in Brazilian Portuguese* livreto *'booklet'*

Candidates (d) and (e) are ruled out by high-ranking MAXHD(FT)-IO because input segments have been deleted from the head of the foot. Now, if indeed merger of /Cɾ/ clusters in stressed syllables is unattested in this Brazilian Portuguese variety, then IDENT(timing) must dominate OVERLAP, thereby ruling in favor of svarabhakti candidates (a) and (b). Further investigation is required to confirm the prediction made by the opposite ranking OVERLAP » IDENT(timing), namely that merger should be possible under stress although reduction is not.

Finally, MAXHEAD(ONSET)-IO is needed to ensure that only /ɾ/ is deleted from /Cɾ/ clusters appearing in unstressed syllables. In Tableau 7, this constraint rules out candidate (e) in which the head of the onset cluster in the input, [v], is deleted. Since candidate (d) fares best on the remaining constraints, reduction of the cluster to single [v] is optimal.

		(ˈli.vɾu)	MAXHD(ONS)-IO	IDENT(timing)	OVERLAP	MAX-IO
	a.	(ˈli.vuɾu)			*!	
	b.	(ˈli.vᵊɾu)			*!	
	c.	(ˈli.vɹu)		*!		
☞	d.	(ˈli.vu)				*
	e.	(ˈli.ɾu)	*!			*

Tableau 7: *Deletion of* /ɾ/ *from unstressed syllable in Br. Port.* livro *'book'*

Incorporating prosodic head faithfulness into the ranking in (7c), we arrive at the complete ranking for Brazilian Portuguese shown in (10):

(10) Final ranking for southeastern Brazilian Portuguese

MAXHEAD(FOOT)-IO, » IDENT(timing), » MAX-IO

MAXHEAD(ONSET)-IO, OVERLAP

4. *Conclusion*

In this paper, I have explained the behavior of Romance /Cɾ/ by incorporating functional phonetic factors such as intergestural timing into a formal OT analysis. The advantages of such a direct approach are that it exposes the underlying phonetic motivation for the ways in which such clusters may be resolved, and it predicts cross-linguistic variation through a factorial typology of independently motivated constraints.

Notes

[*] This paper is the ongoing extension of work initially presented at the XXXII Linguistic Symposium on Romance Languages held at the University of Toronto on April 19-21, 2002. For helpful comments and discussion, I wish to thank Eric Bakovic, Barbara Bullock, Adamantios Gafos, Nancy Hall, David Heap, Haike Jacobs, Jean-Pierre Montreuil, and Donna Rogers. All errors are my own.

[1] Morais-Barbosa (1983:188) attests to the presence of svarabhakti in European Portuguese: "[O]n trouve souvent, entre /r/ et la consonne qui éventuellement le précède ou le suit, ainsi qu'après un *r* final de mot, un phone vocalique de type [ə] plus ou moins réduit, dénué de valeur phonologique…"

[2] Williams (1962:102) notes similar cases of anaptyxis in the evolution of Latin to Portuguese, e.g., *caravelha* < *cravelha* < *claviculam, sapulcoro* < *sepulcrum.*

[3] In this paper, [ɹ] is employed as a cover symbol to denote an articulation that differs minimally from the rhotic shown in (1) as follows. Apicoalveolar [ɾ] has an extra-short constriction period with no audible frication, while [ɹ] involves a longer constriction accompanied by frication, which may or may not be strident.

[4] While the data in (3) reflect Alonso's (1925) observations of Peninsular Spanish, merger is also widely attested in contemporary American Spanish varieties, e.g., Costa Rica (Calvo Shadid 1995), Ecuador (Argüello 1978). See Lipski (1994) for a broad overview of Latin American Spanish.

[5] Cristófaro-Silva (2000) also documents cases of reduction in Brazilian Portuguese involving lateral liquids. For the purposes of this paper, I set aside these cases and concentrate instead on /Cɾ/ clusters.

[6] Bradley (2001), N. Hall (in progress), and Steriade (1990) develop similar timing-based accounts of svarabhakti.

[7] "The *r* tends to be formed during the articulation of the preceding voiceless stop, invading its release, letting itself in turn be invaded by the voicelessness of the release … Careful speech allows the identity of the sounds to be recovered [TGB]."

[8] "This tendency of the consonant *r* to combine with a dental to form a new consonant, *which is generally a compromise between the two,* is not unknown in other languages [TGB]."

[9] The tokens under spectrographic analysis in these figures were taken from recordings of informal conversation and literary readings involving native Spanish speakers from Costa Rica.

[10] Adamantios Gafos (p.c.) suggests that the "timing" predicate in (5a) and the notion of overlap in (5b) should be formally related in terms of representational primitives (cf. the gestural coordination constraints of Gafos (2002), which refer to specific temporal *landmarks* within gestures such as ONSET, TARGET, C-CENTER, etc.). In contrast, the constraints in (5) assume a lexically-specified Phase Window in the sense of Byrd (1994, 1996), which defines a permissible, gradient *target range* within which the relative timing of adjacent gestures must fall (see the discussion surrounding Figure 2). The phonetic alignment constraints of Zsiga (2000) also specify gestural timing in terms of temporal ranges, although her model assumes that timing is assigned in a post-phonological phonetic implementation component and not specified in the lexical representation.

[11] One might inquire as to whether OVERLAP would reduce the intervening vowel of an input /CVɾV/ sequence, e.g., /CVɾV/ → [CɹV]. The constraint would have no such effect, however, given that the intervening lexically-specified vowel ensures non-adjacency of the surrounding consonantal gestures. Thanks to Haike Jacobs for raising this issue.

[12] A more appropriate interpretation is that MAX-IO refers to the *gestures* comprising segments. This follows from the assumption of the Articulatory Phonology framework that gestures function as phonological primitives as well as units of articulation.

[13] In their analysis of Brazilian Portuguese onset reduction, Goad & Rose (to appear) appeal to prosodic faithfulness MAXHEAD-IO, context-free faithfulness MAX-IO, and syllabic markedness *COMPLEX(ONSET). The present account differs in that MAX-IO constraints interact directly with phonetic constraints on intergestural timing—not with syllabic markedness.

References

Alonso, Amado. 1925. "El grupo *tr* en España y América". *Homenaje a Menéndez Pidal* II, 167-191. Madrid.

Argüello, Fanny. 1978. *The žeísta Dialect of Spanish Spoken in Ecuador: A phonetic and phonological study.* Ph.D. Dissertation, The Pennsylvania State University.

Beckman, Mary, & John Kingston. 1990. *Papers in Laboratory Phonology I: Between the grammar and physics of speech.* Cambridge: Cambridge University Press.

Bradley, Travis. 2001. *The Phonetics and Phonology of Rhotic Duration Contrast and Neutralization.* Ph.D. Dissertation, The Pennsylvania State University.

Browman, Catherine, & Louis Goldstein. 1989. "Articulatory Gestures as Phonological Units". *Phonology* 6, 201-252.

----------. 1990. "Tiers in Articulatory Phonology, with Some Implications for Casual Speech". In Beckman & Kingston (1990), 341-376.

----------. 1991. "Gestural Structures: Distinctiveness, phonological processes, and historical change". *Modularity and the Motor Theory of Speech Perception,* ed. by Ignatius G. Mattingly & Michael Studdert-Kennedy, 313-338. Hillsdale, New Jersey: Lawrence Erlbaum.

----------. 1992. "Articulatory Phonology: An overview". *Phonetica* 49, 155-180.

Byrd, Dani. 1994. *Articulatory Timing in English Consonant Sequences.* Ph.D. Dissertation, University of California, Los Angeles.

----------. 1996. "A Phase Window Framework for Articulatory Timing". *Phonology* 13, 139-169.

Calvo Shadid, Annette. 1995. "Variación fonética de /ɾ/ y /r/ en el habla culta de San José". *Filología y Lingüística* XXI(1), 115-134.

Cho, Taehong. 1998a. "Intergestural Timing and Overlap in Korean Palatalization: An Optimality-Theoretic approach". *Japanese/Korean Linguistics* 8, ed. by David Silva, 261-276. Stanford: CSLI Publications.

----------. 1998b. *The Specification of Intergestural Timing and Overlap: EMA and EPG Studies.* Unpublished M.A. Thesis, University of California, Los Angeles.

Cristófaro-Silva, Thaïs. 2000. "Branching Onsets in Brazilian Portuguese". Paper presented at the *Thirtieth Linguistic Symposium on Romance Languages*, held in Gainesville, Florida, February 2000.

Gafos, Adamantios. 1999. *The Articulatory Basis of Locality in Phonology.* New York: Garland.

----------. 2002. "A Grammar of Gestural Coordination". *Natural Language and Linguistic Theory* 20, 269-337.

Gili Gaya, S. 1921. "La *r* simple en la pronunciación española". *Revista de Filología Española* VIII, 271-280.

Goad, Heather & Yvan Rose. To appear. "Input Elaboration, Head Faithfulness and Evidence for Representation in the Acquisition of Left-edge Clusters in West Germanic". *Fixing Priorities: Constraints in phonological acquisition*, ed. by René Kager, Joe Pater & Wim Zonneveld. Cambridge: Cambridge University Press.

Hall, Nancy. In progress. *Svarabhakti as Segmental Overlap*. Ph.D. Dissertation, University of Massachusetts, Amherst.

Harris, James. 1995. "Projection and Edge Marking in the Computation of Stress in Spanish". *The Handbook of Phonological Theory,* ed. by John Goldsmith, 867-887. Cambridge, Mass.: Blackwell.

Harris, John. 1997. "Licensing Inheritance: An integrated theory of neutralisation". *Phonology* 14, 315-370.

Lenz, Rodolfo. 1892. "Chilenishe Studien". *Phonetische Studien* V, 272-293.

Lipski, John. 1994. *Latin American Spanish*. London: Longman.

Malmberg, Bertil. 1965. *Estudios de fonética hispánica*. Collectanea Phonetica, I. Madrid.

McCarthy, John, & Alan Prince. 1995. "Faithfulness and Reduplicative Identity". *University of Massachusetts Occasional Papers 18: Papers* *in Optimality Theory*, ed. by Jill Beckman, Laura Walsh Dickey & Suzanne Urbanczyk, 249-384. Amherst: GLSA.

Morais-Barbosa, Jorge. 1983. *Études de phonologie portugaise.* Évora: Universidade de Évora.

Navarro Tomás, Tomás. 1918. "Diferencias de duración entre las consonantes españolas". *Revista de Filología Española* V, 367-393.

Prince, Alan, & Paul Smolensky. 1993. "Optimality Theory: Constraint interaction in generative grammar". Ms., Rutgers University, New Brunswick, N.J. & University of Colorado, Boulder, Colo.

Quilis, Antonio. 1988. *Fonética acústica de la lengua española*. Madrid: Editorial Gredos.

----------. 1993. *Tratado de fonología y fonética españolas*. Madrid: Editorial Gredos.

Steriade, Donca. 1990. "Gestures and Autosegments: Comments on Browman and Goldstein's paper". In Beckman & Kingston (1990), 382-397.

Whitney, William D. 1889. *Sanskrit Grammar*. Harvard University Press.

Williams, Edwin B. 1962. *From Latin to Portuguese.* Philadelphia: University of Pennsylvania Press.

Zsiga, Elizabeth. 2000. Phonetic Alignment Constraints: Consonant overlap and palatalization in English and Russian. *Journal of Phonetics* 28, 69-102.