Working Draft, May 2002
Comments welcome: tgbradley@ucdavis.edu

Gestural Timing and Derived Environment Effects in Norwegian Clusters

Travis G. Bradley
University of California, Davis

1. Introduction

This paper considers the phonological behavior of /ɾC/ clusters in Urban East Norwegian (henceforth UEN), as recently discussed by Kristoffersen (2000). I will argue that the phonetic realization of such clusters depends on the relative timing of the articulatory gestures associated with /ɾ/ and the following consonant. Specifically, the patterning of /ɾC/ clusters lends further support to Cho's (1998a,b) phonetically-based Optimality-theoretic (OT) approach to intergestural timing specifications. Cho's central hypothesis is that "the timing between two gestures created by morpheme concatenation is not lexically specified and is therefore potentially subject to any phonological change which can be produced by varying gestural overlap" (Cho 1998b:5). This hypothesis provides a basis for explaining derived environment effects whereby overlap in /ɾC/ sequences is blocked within morphemes but not across morpheme or word boundaries.

This paper is organized as follows. Section 2 documents the derived environment effects in UEN clusters. Section 3 examines the role of gestural timing in cluster realization. Section 4 develops a phonetically-based analysis of the derived environment effects, which is then compared with two alternative OT accounts in Section 5. Finally, Section 6 concludes by considering some empirical implications of the proposed analysis, with specific reference to liquid assimilation processes observed in the Spanish of Havana, Cuba.

* For their comments and reactions, I wish to thank Eric Bakovic, Lev Blumenfeld, Patrik Bye, Adamantios Gafos, Nancy Hall, Armin Mester, Richard Page, Joe Pater, Leendert Plug, Jason Riggle, Hanne Gram Simonsen, and members of the WCCFL 21 audience. All errors are mine.

 WCCFL 21 Proceedings, ed. L. Mikkelsen and C. Potts, pp. 101-114. Somerville, MA: Cascadilla Press.

2. Derived environment effects in UEN clusters

In UEN, the realization of /ɾC/ clusters is conditioned phonologically by the place specification of the second consonant and morphosyntactically by the presence of an intervening morpheme or word boundary. The laminal (denti-)alveolar series /t, d, s, n, l/ constitutes the unmarked series of coronal consonants. Surface combinations of apicoalveolar tap /ɾ/ + laminal /t, s, n, l/ do not occur within the morpheme and are instead realized phonetically as single apicals [ʈ, ʂ, ɳ, ɭ], as shown in (1) below. (Note: All data are from Kristoffersen (2000), with relevant page numbers indicated.)

(1)	*svart*	[svɑʈ]	'black'	*barn*	[bɑːɳ]	'child'	(88)
	vers	[væʂ]	'verse'	*jarl*	[jɑːɭ]	'earl'	

However, there are some exceptions to the realization of tautomorphemic /ɾ/ + laminal clusters as single apicals. Kristoffersen (2000:89) observes that surface combinations of [ɾd] are common and that /ɾ/ + laminal clusters may or may not be pronounced as single apicals in some words:[1]

(2)	*sve*[ɾd]	'sword'	*Stu*[ɾ.l]*a* ~ *Stu*[.ɭ]*a*	(names)
	no[ɾ.n]*e* ~ *no*[.ɳ]*e*	'norn'	*Zo*[ɾn] ~ *Zo*[ɳ]	

Finally, the data in (3) show that /ɾ/ surfaces intact before tautomorphemic non-coronal consonants:

(3)	*larm*	[lɑɾm]	'noise'	*merke*	[mæɾ.kə]	'mark'	(43)
	skarp	[skɑɾp]	'sharp'	*kork*	[kɔɾk]	'cork'	(55)
	verb	[væɾb]	'verb'	*sorg*	[sɔɾg]	'sorrow'	

In derived environments, /ɾC/ clusters exhibit a different pattern. Across morphological and syntactic boundaries, all sequences of /ɾ/ + laminal /t, d, s, n, l/ are phonetically merged without exception to corresponding single apicals [ʈ, ɖ, ʂ, ɳ, ɭ], as shown in (4) and (5).[2] (Note: Obligatory merger is shown in boldface.)

---

1. The exceptionality of /d/ in non-derived environments is limited to central parts of East Norway. In other regions, single apical realizations of historical /ɾd/ are common, e.g., *sverd* [svæɖ] 'sword' (Kristoffersen 2000:88, Fn. 36).
2. Some eastern and northern Norwegian varieties also have an apical flap /ɽ/ which alternates with [ɾ] and [l] under certain conditions and may also merge phonetically with following laminals. An exhaustive treatment of the flap is beyond the scope of this paper, but see Kristoffersen (2000:88-96).

(4)	*vårtegn*	/vɔr-tejn/	[vɔː.**ʈ**æjn]	'spring sign'	(316)
	vårdag	/vɔr-dag/	[vɔː.**ɖ**ɑːg]	'spring day'	
	vårsol	/vɔr-sul/	[vɔː.**ʂ**uːl̩]	'spring sun'	
	vårnatt	/vɔr-nat/	[vɔː.**ɳ**ɑt]	'spring night'	
	vårluft	/vɔr-luft/	[vɔː.**ɭ**ʉft]	'spring air'	

(5)	*for noen*	[fɔ.**ɳ**uː.un]	'for some'	(312)
	herr Tellefsen	[hæ.**ʈ**ɛl.lɛf.sn̩]	'Mr. Tellefsen'	
	Det gleder noen.	[də.gleː.də.**ɳ**uː.un]	'It pleases some.'	
	Per ser en stor løve.	[peː.**ʂ**eː.rɛn.stuː.**ɭ**øː.və]	'Per sees a big lion.'	(317)

Before non-coronal consonants, however, morpheme-final /ɾ/ undergoes optional deletion. Kristoffersen (2000:180) observes that prefix-final /ɾ/ usually deletes in informal speech before stem-initial non-coronals. Similar behavior is found with respect to heteromorphemic /ɾ/ + non-coronal clusters in compounds and across word boundaries in the syntax. Rhotic deletion is an optional process conditioned by extralinguistic factors such as rate and register of speech, as well as the social background of the speaker.[3] The following data show optional deletion across prefix boundaries in (6), and in compound formation and across word boundaries in (7):

(6)	*erklære*	/eɾ-klæɾe/	[æ(ɾ).klæː.ɾə]	'to declare'	(180)
	forbanne	/foɾ-banne/	[fɔ(ɾ).bɑn.nə]	'to curse'	
	forklare	/foɾ-klaɾe/	[fɔ(ɾ).klɑː.ɾə]	'to explain'	(337)

(7)	*værmelding*	[væː(ɾ).mɛl.liŋ]	'weather forecast'	(183)
	(cf. *vær* [væːɾ] 'weather')			
	herr Kristensen	[hæ(ɾ).kɾis.tn̩.sn̩]	'Mr. Kristensen'	(312)
	Det gleder mange.	[də.gleː.də(ɾ).mɑŋ.ŋə]	'It pleases many.'	

Finally, the data in (8) and (9) show that morpheme-final /ɾ/ fails to delete before vowels, resyllabifying instead to the following onset:[4]

3. Deletion of word-final /ɾ/ is also subject to a set of intricate prosodic conditions (Kristoffersen 2000:311-5). Furthermore, Hanne Gram Simonsen (p.c.) points out that deletion is not possible in some words containing the prefixes /eɾ-/ and /foɾ-/, which is suggestive of lexical exceptions. I abstract away from these complexities since a meticulous examination would lead us too far afield.

4. The final /ɾ/ of the auxiliary verbs *blir* 'becomes', *er* 'is', *var* 'was' and *har* 'has' is somewhat exceptional. When pronounced without stress, these verbs exhibit deletion of /ɾ/ before both vowels and non-coronals, while merger applies as expected before laminals (Kristoffersen 2000:312).

(8)	*erobre*	/eɾ-obɾe/	[æ.ɾuː.bɾə]	'to conquer'	(180)
	forakte	/foɾ-akte/	[fɔ.ɾɑk.tə]	'to despise'	
(9)	*væromslag*		[ʋæː.ɾɔm.ʂlɑːg]	'change of weather'	(183)
	(cf. *vær* [ʋæːɾ] 'weather')				
	herr Andersen		[hæ.ɾɑn.nə.ʂn̩]	'Mr. Andersen'	(312)
	Det gleder alle.		[də.gleː.də.ɾɑl.lə]	'It pleases everybody.'	

In summary, the obligatory phonetic merger of heteromorphemic /ɾ/ + laminal clusters and the optional deletion of /ɾ/ before morpheme-initial non-coronals show that these processes apply in derived environments created by morphological or syntactic concatenation. The existence of lexical exceptions to merger and the lack of deletion within the morpheme demonstrate the failure of such processes to apply in non-derived environments. Therefore, UEN merger and deletion may be seen as an instance of morphological Non-Derived Environment Blocking in the sense of Kiparsky (1993). Kristoffersen (2000) argues that if merger of /ɾ/ + laminal clusters is blocked from applying within the morpheme, then non-derived apicals must be analyzed as the underlying vestiges of historical clusters: "lexical items which formerly contained such clusters are assumed [to] have underlying apicals in the synchronic grammar" (p. 88). Therefore, the adjective *svart* 'black' in (1) must be represented underlyingly as /sʋaʈ/. In contrast, the intact [ɾd] sequence of monomorphemic *sverd* 'sword' in (2) reflects underlying /ɾd/, whereas the alternation between *Stu*[ɾ.l]*a* and *Stu*[.l̩]*a* follows from the assumption of alternate underlying forms /stʉɾla/ and /stʉl̩a/.

3. The role of gestural timing in UEN cluster realization

To understand the phonetic basis of merger and deletion in /ɾC/ clusters, some discussion of the apicoalveolar tap is in order. Walsh (1997:96) notes that cross-linguistically, taps tend to prefer intervocalic position and to avoid word-edges in order to maintain sonority and enhance perceptibility. Others have observed that in many languages, a *svarabhakti* vowel fragment typically intervenes between the tap and an adjacent consonant.[5] This fragment has formant structure similar to the nuclear vowel appearing on the opposite side of the tap constriction. (See Quilis 1993:337-32 on the acoustic properties of svarabhakti in Spanish.) Walsh's (1997:141) charac-

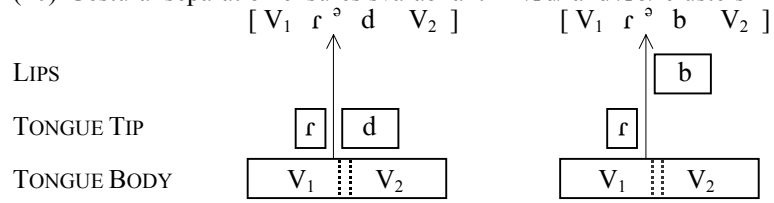
5. Whitney (1889) employs the term *svarabhakti* to denote the vowel-like fragment that intervenes between the retroflex rhotic and an adjacent stop or spirant in Sanskrit. Early descriptions of svarabhakti in Spanish are found in Lenz (1892).

terization of the tap as "a quick coronal interruption of surrounding segments" provides a perceptual basis for understanding both the distributional preferences of /ɾ/ and the phenomenon of svarabhakti. While flanking full vowels automatically guarantee an optimal acoustic backdrop, the intervening svarabhakti vowel fragment ensures recoverability of the extra-short tap constriction in adconsonantal position. The preference for intervocalic position stems from the fact that svarabhakti may be perceptually compromised in non-intervocalic positions by differences in gestural timing. In the absence of svarabhakti, the brief tap constriction is less likely to be recovered.

Articulatory Phonology (Browman & Goldstein 1989, 1990, 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. This framework posits that phonetic timing is intrinsic to the phonological representation, and gestures are phonological primes as well as units of articulation. Consonantal gestures are superimposed on vocalic gestures, which are articulatorily adjacent (see Gafos 1999). This explains why the svarabhakti fragment is always a continuation of the formant structure present 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 tapping gesture produces a brief interruption separating the two. (See Bradley 2001, N. Hall 2002, and Steriade 1990 on the role of gestural timing in producing svarabhakti).

Consider the gestural timing scenarios for hypothetical /ɾd/ and /ɾb/ clusters in UEN shown in (10):

(10) Gestural separation ensures svarabhakti in /ɾd/ and /ɾb/ clusters[6]



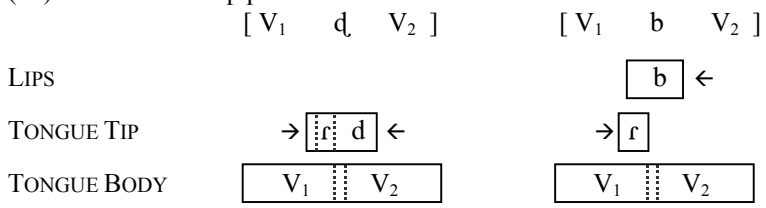
When the oral gesture for /ɾ/ is temporally separated from that of the following consonant, the overlapping tongue body gesture for V_1 is recovered as a svarabhakti fragment, narrowly transcribed here as [ə]. The presence of this intervening fragment ensures the perceptibility of the tap constriction,

6. 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 dotted lines (e.g., the tongue body gestures for V_1 and V_2).

thereby preventing both the phonetic merger of /ɾ/ and the following laminal in [ɾʲd] and the deletion of /ɾ/ before the non-coronal in [ɾʲb].[7]

On the other hand, no svarabhakti fragment can be recovered when the oral gestures for /ɾ/ and the following consonant are overlapped, as in (11). (Note: Arrows indicate temporal realignment and consequent overlap.)

(11) Gestural overlap precludes svarabhakti in /ɾd/ and /ɾb/ clusters



According to Browman & 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 *blending* of the characteristics of the two gestures, which "shows itself in spatial changes in one or both of the overlapping gestures" (p. 362). Merger of /ɾd/ in (11) plausibly results from the blending of adjacent tongue tip gestures. Such an explanation is motivated by recent phonetic studies of Norwegian coronal stops (Moen & Simonsen 1997, 1998; Simonsen, Moen & Cowen 2000), in which electropalatographic measurements show considerable variation and overlap in the contact area of derived apicals [ʈ, ɖ] in comparison with corresponding laminals [t, d]. That is, the derived apicals do not always exhibit significantly more posterior contact than their laminal counterparts, which suggests that the traditional classification of apicals as posterior retroflex articulations is inaccurate. One interpretation of these results is that derived apicals [ʈ, ɖ] result from the blending of characteristics of the tongue tip gestures for apicoalveolar /ɾ/ and a following (denti-) alveolar laminal. While the resultant tongue tip configuration retains the apicality of /ɾ/, variation in contact area reflects a gradient compromise between the lexically specified constriction locations of the adjacent tongue tip gestures.[8]

---

7. Adamantios Gafos (p.c.) suggests that the temporal gap between oral gestures is unlikely to be the same for both [ɾʲd] and [ɾʲb] in (10), although nothing crucial seems to hinge on this potential difference in the account developed in this paper.

8. Dutch provides further corroborating evidence. In non-emphatic speech, coronal plosives are often realized as apico-postalveolar after /r/, which is itself subject to elision. Plug (2002) proposes a gestural account in which blending stems from greater temporal overlap between the gestures for /r/ and the following coronal.

In contrast, overlap between two gestures *across tiers* will not affect the trajectories of either gesture since different articulators can behave independently of one another. A possible consequence of cross-tier overlap is that one gesture may be perceptually hidden by another, resulting in cases of apparent deletion (Browman & Goldstein 1990:360-2).[9] It is conceivable that the deletion of /ɾ/ before non-coronals in UEN takes place as shown in (11), in which the following bilabial gesture for /b/ obscures the svarabhakti vowel fragment that is crucial for the recoverability of the tap constriction. This explanation receives some motivation from the fact that deletion in derived environments tends to occur in informal speech (Kristoffersen 2000:180). In the Articulatory Phonology model, casual speech processes are seen as "consequences of variation in the overlap and magnitude of gestures" (Browman & Goldstein 1990:371). Since gestures tend to overlap more in casual speech, the greater frequency of deletion in informal styles lends support to an account in terms of the overlap-induced perceptual masking of /ɾ/ before non-coronals.

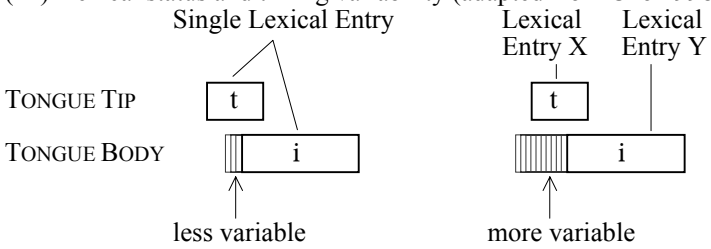
4. An account of the derived environment effects in UEN clusters

Cho (1998a,b) accounts for derived environment effects in Korean palatalization by incorporating functional phonetic factors such as intergestural timing into a formal analysis couched within OT (Prince & Smolensky 1993, McCarthy & Prince 1995). In Korean, /t/ is palatalized before /i/ only in environments derived by morphological concatenation: /mati/ → [madi] 'knot' versus /mat-i/ → [madʒi] 'the eldest'. (Note: Obstruents are voiced intervocalically by an independent process.) Cho's central hypothesis is that the timing relationship between adjacent gestures is less variable within a *single* lexical entry than across *different* lexical entries. While the timing between two gestures in the same lexical entry is preserved in the output, "the timing between two gestures created by morpheme concatenation is not lexically specified and is therefore potentially subject to any phonological change which can be produced by varying gestural overlap" (Cho 1998b:5). On the assumption that palatalization stems from greater overlap between the gestures for /t/ and /i/, the derived environment effect can be explained as follows. Lexically specified timing for the /ti/ sequence in monomorphemic /mati/ 'knot' is preserved in the output, precluding palatalization.

9. As an example, Browman & Goldstein (1990:361) cite the apparent deletion of English final /t/ in the casual speech form [mʌsbi] versus the canonical form [mʌst#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.

However, the /t-i/ sequence in heteromorphemic /mat-i/ 'the eldest' has no lexical timing specification, which permits the two gestures to overlap, thus yielding surface palatalization. The relation between lexical status and timing variability in /ti/ versus /t-i/ is schematized in (12):

(12) Lexical status and timing variability (adapted from Cho 1998b:7)



The derived environment effects observed in UEN clusters suggest a similar analysis. In tautomorphemic /ɾC/, the gestures for /ɾ/ and the following consonant belong to the same lexical entry and are timed in such a way as to ensure recovery of the tap constriction. This lexically specified timing relation is preserved on the surface, producing intact [ɾ^{ə}d] and [ɾ^{ə}b] clusters as shown in (10). However, the same gestures in heteromorphemic clusters have no lexically specified timing relation because they belong to different lexical entries. In derived environments, therefore, the gestures for /ɾ/ and the following consonant may overlap, thereby yielding merger and deletion as shown in (11). This account can be formally implemented in the OT framework with the following constraints:[10]

(13) a. IDENT(timing) (cf. Cho 1998b:6)
Intergestural timing belonging to the same lexical entry must be preserved in the output.
b. OVERLAP (cf. Cho 1998b:37)
Adjacent consonantal gestures must be overlapped.

10. Adamantios Gafos (p.c.) suggests that the "timing" predicate in (13a) and the notion of overlap in (13b) 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 (13) assume a lexically-specified Phase Window in the sense of Byrd (1996), which defines a permissible, gradient *target range* within which the relative timing of adjacent gestures must fall. 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.

The ranking IDENT(timing) » OVERLAP has the effect of prohibiting gestural overlap in tautomorphemic /ɾC/, as shown in tableau (14):

(14) Merger and deletion blocked in tautomorphemic /ɾC/

	IDENT(timing)	OVERLAP
☞ a. /Vɾˤd/ → Vɾˤd		*
b. /Vɾˤd/ → Vd̰	*!	
☞ c. /Vɾˤb/ → Vɾˤb		*
d. /Vɾˤb/ → Vb	*!	

In the case of heteromorphemic /ɾC/, IDENT(timing) becomes irrelevant because the adjacent gestures belong to different lexical entries and, therefore, have no lexically specified timing relation. Now, recall that across morpheme and word boundaries, merger of /ɾ/ with a following laminal is obligatory, whereas deletion of /ɾ/ before a non-coronal is optional. The MAX(feature) constraint in (15) permits an account of this difference:

(15) MAX(apical)
An apical specification in the input must be recovered in the output.

Crucially, MAX(apical) enforces preservation of the apicality of input /ɾ/, even when the rhotic itself is not present in the auditory representation. It is insufficient to invoke a constraint demanding identical apical specification of segmental correspondents, such as IDENT(apical) (cf. McCarthy & Prince 1995). If input /ɾ/ is deleted, then it has no correspondent in the output, and IDENT(apical) would be vacuously satisfied. Rather, identity must be evaluated directly between input and output features and not segments.

Tableau (16) demonstrates how MAX(apical) captures the difference between obligatory merger and optional deletion in derived environments:

(16) Obligatory merger versus optional deletion in heteromorphemic /ɾC/

	IDENT(timing)	OVERLAP	MAX(apical)
a. /Vɾ/ + /d/ → Vɾˤd		*!	
☞ b. /Vɾ/ + /d/ → Vd̰			
c. /Vɾ/ + /d/ → Vd			*!
☞ d. /Vɾ/ + /b/ → Vɾˤb		*	
☞ e. /Vɾ/ + /b/ → Vb			*

Although both (16b,c) satisfy OVERLAP, (16c) violates MAX(apical) because the apicality of input /ɾ/ is not maintained in the output. Candidate

(16b) is optimal because same-tier overlap blends the adjacent tongue tip gestures to produce an apical articulation in the output, thereby allowing recovery of input apicality. Candidate (16d) violates OVERLAP due to the temporal separation of consonantal gestures, and candidate (16e) violates MAX(apical) because cross-tier overlap perceptually masks the apical specification of input /ɾ/, leading to its absence from the auditory representation.[11] Since (16d,e) receive the same number of violations, both are predicted to be possible outputs, which reflects the optionality of deletion.

The difference between obligatory merger and optional deletion is ultimately related to the difference between gestural overlap within tiers versus across tiers. Merger in (16b) is obligatory in derived environments because when faithfulness to lexical timing is irrelevant, gestural blending satisfies the preference for overlap while simultaneously preserving the apicality of input /ɾ/. In contrast, such an optimal solution is not available when /ɾ/ precedes a non-coronal consonant because overlap between gestures on different tiers does not result in blending. Rather, overlap between the bilabial gesture of /b/ and the tongue tip gesture of /ɾ/ can lead only to the perceived deletion of the latter.[12, 13]

5. Comparison with alternative accounts

Let us examine two possible OT alternatives to the account just developed. In Lubowicz (1998), morphological alternations result from the violation of locally-conjoined stem:syllable anchoring and markedness constraints. Given the constraints in (17a,b) and the ranking schema in (17c),

11. Even if (16e) retains articulatory traces of the tongue tip gesture for /ɾ/ in a manner similar to Browman & Goldstein's (1990:361) example of English [mʌsbi] 'must be' (see Fn. 9), such an apparent deletion would still be consistent with the present account since MAX(apical) in (15) is defined on the auditory dimension.

12. This account resonates well with Honorof's (1999:68) diachronic explanation of the weakening of the tongue tip gesture for preconsonantal /n/ in Castilian Spanish: "Weakened [nasal] coronals in the context of non-coronals could eventually lead to loss altogether if the release of the weakened coronal is often obscured by the non-coronal, but would not be expected to obtain at all as a consequence of overlap in the case of coronal + coronal sequences where blending results in a single release carrying potentially salient information about both consonants."

13. Although mirror-image heteromorphemic /Cɾ/ might be expected to pattern in a manner similar to /ɾC/ in (16), relevant data from Kristoffersen (2000:45) suggest otherwise. Addition of the present tense suffix /-ɾ/ to a C-final verb stem yields a phonetically intact cluster: /kast-ɾ/ [kɑs.tʂ] 'throw', /bak-ɾ/ [bɑː.kʂ] 'bake'. A possible analysis of such clusters might involve a high-ranking constraint requiring the present tense morpheme /-ɾ/ to receive overt phonological exponence, e.g., REALIZEMORPHEME (Kurisu 2001). Thanks to Armin Mester for raising this issue.

we may posit the constraint ranking in (17d) as a possible analysis of the derived environment effects observed in UEN /ɾC/ clusters:

(17) a. R-ANCHOR(Stem; σ) (Lubowicz 1998:24)
The rightmost segment of a stem in the input has a correspondent at the right edge of a syllable in the output.
b. *ɾC
No apicoalveolar tap + consonant sequences.
c. $[\text{MARK}_i \,\&\, \text{R-ANCHOR(Stem; σ)}]_{\text{Domain}}$ » FAITH » MARK_i
where MARK_i is a markedness constraint inducing the alternation
d. $[*ɾC \,\&\, \text{R-ANCHOR(Stem; σ)}]_{\text{AdjacentSegments}}$ » MAX » *ɾC

Since there are instances of intact /ɾC/ clusters within the morpheme (see (2) and (3) above), the markedness constraint against such clusters must be ranked below the faithfulness constraint seeking to maintain /ɾ/ in the output, hence the ranking MAX » *ɾC in (17d). Following the constraint schema in (17c), *ɾC would be locally conjoined with stem:syllable anchoring within the domain of adjacent segments.

According to Lubowicz (1998), resyllabification of a stem-final segment violates stem:syllable anchoring, thereby activating the markedness constraint responsible for an alternation in derived environments. This account is problematic in the case of UEN clusters because the derived environment effect does not involve concomitant resyllabification of stem-final /ɾ/, but rather its deletion. We might view deletion as a violation of R-ANCHOR(Stem; σ) as defined in (17a), since /ɾ/, the rightmost segment of a stem in the input, would have no correspondent at the right edge of a syllable in the output. However, this interpretation does not save the analysis because deletion also satisfies the markedness constraint *ɾC. Since R-ANCHOR(Stem; σ) and *ɾC are never simultaneously violated, the higher ranked conjunction of these two constraints is never violated, and no alternation can be produced. This problem is illustrated with the compound *værmelding* 'weather forecast' in tableau (18), where the 💣 symbol denotes an incorrectly optimized output.

(18) Local conjunction cannot yield deletion of stem-final /ɾ/

/væɾ/ + /mɛlliŋ/	{*ɾC & R-ANCHOR}$_{\text{AdjSeg}}$	MAX	*ɾC	R-ANCHOR
💣 a. væːɾ.mɛl.liŋ			*	
b. væː.mɛl.liŋ		*!		*

Even if the above analysis could be made to work, deletion of prefix-final /ɾ/ would still be problematic. Since R-ANCHOR(Stem; σ) applies only to stem-final segments, any segment that is not stem-final in the input will

vacuously satisfy this constraint. Therefore, no higher ranked conjunction involving R-ANCHOR(Stem; σ) can be violated by changes suffered by prefix-final /ɾ/, thus leading to an incorrect outcome similar to (18a).

Let us consider another approach to the deletion of prefix-final /ɾ/. Recall that deletion is blocked before non-coronals within the morpheme, as in *larm* [lɑɾm] 'noise' in (3). McCarthy & Prince (1995) propose a universal metaconstraint of ROOT-FAITH » AFFIX-FAITH whereby faithfulness to input specifications is greater within roots than within affixes. If the markedness constraint *ɾC is ranked between MAX-ROOT and MAX-AFFIX, then the deletion of prefix-final /ɾ/ versus its faithful realization in roots can be accounted for as follows:

(19) Faithfulness in roots versus deletion in prefixes

	MAX-ROOT	*ɾC	MAX-AFFIX
☞ a. /lɑɾm/ → lɑɾm		*	
b. /lɑɾm/ → lɑm	*!		
c. /foɾ/ + /banne/ → fɔɾ.bɑn.nə		*!	
☞ d. /foɾ/ + /banne/ → fɔ.bɑn.nə			*

However, the Root-Affix faithfulness account falls short when an initial compound member ends with /ɾ/ and the second compound member begins with a non-coronal consonant:[14]

(20) Root faithfulness cannot yield deletion of stem-final /ɾ/ in compounds

/væɾ/ + /mɛliŋ/	MAX-ROOT	*ɾC	MAX-AFFIX
💣 a. væːɾ.mɛl.liŋ		*	
b. væː.mɛl.liŋ	*!		

In contrast, the derived environment effects in UEN follow straightforwardly under the phonetically-based OT account developed in Section 4. Since faithfulness to input timing is inactive across lexical (morphological or syntactic) boundaries, the preference for gestural overlap is free to exert its effects, thereby producing both phonetic merger and deletion.

14. In articulating a theory of head dominance, Revithiadou (1999) derives the effects of Root-Affix faithfulness from the ranking HEAD-FAITH » FAITH, whereby lexical accents sponsored by morphological heads are given priority over other accents within the word. However, a ranking such as MAX-HEAD » *ɾC » MAX does not remedy the deletion problem, as tonal accent in UEN compounds is controlled by properties of the first compound member (Kristoffersen 2000:263). If indeed /væɾ/ in (20) enjoys headship status, then MAX-HEAD would incorrectly forbid deletion as does MAX-ROOT. Thanks to Jason Riggle for discussion on this point.

6. Empirical implications and conclusion

In this paper, I have argued that the ranking IDENT(timing) » OVERLAP is responsible for the blocking of merger and deletion in non-derived /ɾC/ clusters in UEN. The opposite ranking predicts that merger and deletion will affect such clusters in an across-the-board fashion, irrespective of morphosyntactic boundaries. This prediction is potentially borne out in the Spanish of Havana, Cuba, in which coda liquids participate in several intricate patterns of neutralization, retroflexion and place assimilation, both within and across word boundaries (Harris 1985, Padgett 1995). Before coronal consonants, liquids are neutralized via retroflexion, to which the following coronal assimilates progressively. Before non-coronals, coda liquids assimilate regressively in all features but voicing. The distinct patterning of preconsonantal liquids suggests a possible parallel to the overlap account of UEN merger and deletion as same-tier blending versus cross-tier perceptual masking, respectively.[15] I leave it to future research to determine whether the complexities of Havana Spanish liquid + consonant clusters may be subsumed under the gestural approach developed in this paper.

References

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. PhD Dissertation, Penn State University. [ROA 473.]

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.

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

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

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

----------. 1998b. The Specification of Intergestural Timing and Overlap: EMA and EPG Studies. Unpublished MA Thesis, UCLA.

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

15. Padgett (1995) is the first to consider the possibility of an overlap account for Havana Spanish clusters, although he ultimately rejects such an analysis in favor of a phonological feature spreading rule (see the arguments given on pp. 120-1).

----------. 2002. A Grammar of Gestural Coordination. *Natural Language and Linguistic Theory* 20, 269-337. [ROA 462.]

Hall, Nancy. 2002. Svarabhakti as Gestural Overlap. Talk presented at LSA, San Francisco, California, January 2002.

Harris, James. 1985. Autosegmental Phonology and Liquid Assimilation in Havana Spanish. In L. King & C. Mahey, eds., *Selected Papers from the XIIIth Linguistic Symposium on Romance Languages,* 127-148. Philadelphia: John Benjamins.

Honorof, Doug. 1999. Articulatory Gestures and Spanish Nasal Assimilation. PhD Dissertation, Yale University.

Kiparsky, Paul. 1993. Blocking in Non-derived Environments. In Sharon Hargus & Ellen Kaisse, eds., *Phonetics and Phonology 4: Studies in Lexical Phonology,* 277-313. San Diego: Academic Press.

Kristoffersen, Gjert. 2000. *The Phonology of Norwegian.* Oxford: Oxford University Press.

Kurisu, Kazutaka. 2001. The Phonology of Morpheme Realization. PhD Dissertation, UC Santa Cruz. [ROA 490.]

Lenz, Rodolfo. 1892. Chilenishe Studien. *Phonetische Studien* 5, 272-293.

Lubowicz, Anna. 1998. Derived Environment Effects in OT. [ROA 239.]

McCarthy, John, & Alan Prince. 1995. Faithfulness and Reduplicative Identity. *UMOPL* 18, 249-384. [ROA 60.]

Moen, Inger, & Hanne Gram Simonsen. 1997. Effects of Voicing on /t̬,d̬/ Tongue/palate Contact in English and Norwegian. *Proceedings from Eurospeech* '97, 2399-2402.

----------. 1998. Kontaktmønstre for apikale plosiver, /t̬,d̬/ i østnorsk. In J.T. Faarlund, B. Mæhlum & T. Nordgård, eds., *Norsk språkvitskap: Utvalde artiklar frå MONS* 7, 154-167. Oslo: Novus.

Padgett, Jaye. 1995. *Stricture in Feature Geometry.* Stanford: CSLI Publications.

Plug, Leendert. 2002. Segmental Deletion as Gestural Realignment: The case of post-vocalic /r/ in Dutch. *Durham Working Papers in Linguistics* 8, 111-124.

Prince, Alan, & Paul Smolensky. 1993. Optimality Theory: Constraint Interaction in Generative Grammar. Ms., Rutgers University; University of Colorado.

Quilis, Antonio. 1993. *Tratado de fonología y fonética españolas.* Madrid: Editorial Gredos.

Revithiadou, Anthi. 1999. Headmost Accent Wins. PhD Dissertation, HIL/Leiden University. [ROA 388.]

Simonsen, Hanne Gram, Inger Moen, & Steve Cowen. 2000. Retroflex consonants in Norwegian: Are they really? Evidence from EPG and EMA. *Proceedings, 5th Seminar on Speech Production: Models & Data.*

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

Walsh, Laura. 1997. The Phonology of Liquids. PhD Dissertation, UMass, Amherst.

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

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