COMPENSATORY LENGTHENING IN HARMONIC SERIALISM*

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June 2011

1 Introduction

Informally, compensatory lengthening (CL) is a phenomenon that consists of two parts: the deletion of a weight-bearing segment, and the concomitant lengthening of another, usually adjacent segment. Unsurprisingly, analyses of CL are usually derivational in that lengthening only occurs after it is triggered by deletion of a neighboring segment. Less discussed is the fact that, because CL is triggered only by the loss of moraic segments, both of these steps must refer to a syllabified and moraically specified form. Only coda consonants can be associated with moras, and a particular segment's status as a coda can only be determined after the form has been syllabified. It is crucial, therefore, that syllabification and assignment of moras happen before segmental deletion.

In constraint-based phonology, this requirement for prosodic structure means that faithfulness violations must be evaluated with respect to a form that contains prosodic structure at least up to the level of the syllable. Doing so is not possible in classic Optimality Theory (OT, Prince and Smolensky 1993/2004), a framework that disallows intermediate levels of representation. Moreover, it is not immediately obvious that Harmonic Serialism (HS; McCarthy 2000, *et seq.*), an iterative version of OT, allows for this particular intermediate stage. Even in HS, there is no guarantee that the correct syllabic and moraic structure will be built before segmental changes occur. I will show that a ranking paradox prevents the building of prosodic structure from intrinsically preceding deletion of segments. Similarly, it is not possible to use gradual deletion of consonants to force the consonant to remain in the derivation long enough to obtain the proper moraic specification. I argue, though, that an analysis of CL is possible in HS if we make the auxiliary assumption that the derivation begins with a fully faithful candidate (FFC, McCarthy 2007). I will then show that HS can derive the most canonical type of CL using a mora-sharing approach. Some of the more complex interactions between deletion and lengthening can also be analyzed straightforwardly in this framework. Cases that the analysis cannot account for, namely nonlocal interactions, are extremely rare, and it is a strength of the analysis that it can account for most variations on canonical CL without difficulty.

1.1 Properties of CL

Compensatory lengthening is traditionally described as "the lengthening of a segment triggered by the deletion or shortening of a nearby segment" (Hayes, 1989; 260). In the most canonical type of CL, and the one I will focus on in this paper, deletion of an underlying consonant causes lengthening of a preceding vowel, as schematized in (1).[1] Across languages, though, triggers for CL take many forms: formation of a glide from an underlying vowel can cause lengthening of a following vowel, an underlying nasal consonant surfacing as prenasalization of a following consonant can cause lengthening of a preceding vowel, *etc.* CL

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[*] Many thanks to Armin Mester, Jaye Padgett, Dave Teeple, Donka Farkas and the participants of the Winter 2011 Research Seminar (thanks especially to Mark Norris and Oliver Northrup), Melissa Frazier, Bruce Hayes, Junko Itô, and Matt Tucker for their helpful discussion and advice. All errors remain my own.

[1] While Hayes (1989) calls this "classic" CL, I will use the term "canonical CL" to emphasize the fact that CVC → CV: is the most common type of CL.

is a cross-linguistically common synchronic process. Section 2 illustrates canonical synchronic CL in various languages, including Japanese, Kabardian, Komi, Lithuanian, Luganda, Ngajan, colloquial Farsi, and colloquial Turkish.

(1) /CVC/ → [CVː]

CL is never caused by the loss of an onset; it is always triggered by loss of a coda or other moraic segment. Furthermore, the deleted and lengthened segments are always tautosyllabic.[2] In the Ižma dialect of Komi, for example, /l/ deletes with CL of the preceding vowel when the /l/ is word-final or stem-final and followed by a consonant (Data from Kavitskaya 2002, p. 53; see Batalova 1982, p. 20–27 for more discussion):

		‘hear-1.SG.PAST’	‘hear-INF’
(2)	Underlying representation:	/kil-i/	/kɨl-ni/
	Syllabification:	kɨ.li	kɨl.ni
	Surface form:	[kɨli]	[kɨːnɨ]

		‘horse-ELATIVE.SG’	‘horse.NOM.SG’
(3)	Underlying representation:	/vøl-ys/	/vøl/
	Syllabification:	vø.lys	vol
	Surface form:	[vølys]	[vøː]

This pattern results from the generalization that only the loss of a moraically specified segment triggers CL. Among consonants, only codas are associated with moras, and the fact that CL is triggered only by the loss of coda consonants is a robust cross-linguistic generalization. That is, there are no languages in which CL has convincingly been argued to be triggered by the loss of an onset consonant.

1.2 Outline

This paper begins with an overview of the types of CL processes that occur synchronically in natural languages. I will focus on canonical types of CL, but Section 2 reviews a wide variety of trigger types and conditions. Section 3 summarizes some of the previous approaches to CL. These include autosegmental and phonetic analyses, but the focus is on versions of OT: Shaw’s (2007) OT-CC approach and the limitations of classic OT when it comes to the opacity inherent in CL. I turn to Harmonic Serialism in Section 4, detailing the problems CL poses for that framework. I propose revisions to the constraint set that alleviate some of those problems. In Sections 5 and 6, I contrast two approaches to a Harmonic Serialist analysis of CL. The first, which makes use of McCarthy’s (2008a) theory of gradual deletion of consonants, will be shown to both be empirically inadequate and make undesirable theoretical predictions. The other analysis utilizes a fully faithful candidate, which introduces syllabification and moraic structure early in the derivation. This latter analysis is shown to be superior in that it it able to correctly derive more types of CL and in that, unlike the gradual deletion approach, the intermediate stages it predicts are typologically attested. I conclude in Section 7 with some general observations and directions for future research.

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[2] An important exception to this generalization is so-called CVCV CL, schematized in (i). I will assume that this is a different phenomenon—perhaps preservation of some higher level of prosodic structure like the foot—and I will have nothing to say about CVCV CL in this paper.

(i) /CVCV/ → [CVːC]

2 Synchronic CL

Synchronic CL is a widely attested phenomenon cross-linguistically. An incomplete list of languages exhibiting synchronic CL follows.[3]

Japanese Loanwords from English words ending in *-ium* surface as ending in *-uumu* or *-yuumu*, depending on whether the preceding consonant allows *y* to follow it. In either case, glide formation is assumed to have occurred to prevent *iu* sequences from surfacing:

(4) /bar+iumu/ → [barjuumu] ‘barium’ (Poser 1985, (20))

The process also occurs in lexical items that are native to Japanese, but the language contains very few underlying /iu/ sequences. The one very common native Japanese word to exhibit this pattern is /iu/ ‘I say’, which surfaces as [juː].

Kabardian /w/ and /j/ are deleted post-vocalically, and the preceding tautosyllabic vowel is lengthened:

(5) a. /q’əw/ → [q’uː] ‘swan’
b. /bəɡ/ → [biː] ‘enemy’ (Kavitskaya 2002, p. 46)

Some characteristics of the glide are retained in the lengthened V. /əw/ becomes [uː], /aw/ becomes [oː], and /əj/ becomes [iː], a reflex of the height of the deleted glide.

Komi In the Ižma dialect, stem-final /l/ deletes with CL of the preceding vowel when the [l] would otherwise surface in coda position. When /l/ would surface as an onset, no deletion occurs.

(6) a. /kɨl-i/ → [kɨli] ‘hear (1.SG.PAST)’
b. /kɨl-nɨ/ → [kɨːnɨ] ‘hear (INF)’

(7) a. /vøl-ys/ → [vølys] ‘horse (ELATIVE.SG)’
b. /vøl/ → [vøː] ‘horse (NOM.SG)’ (Kavitskaya 2002, p. 53)

Because this pattern is particularly transparent, forms like the ones in (6) will be used throughout this paper as representative of canonical CL. These data are also analyzed by Shaw (2007) in OT-CC. (See Section 3.4 for discussion of the inadequacies of an OT-CC analysis.)

Lithuanian While CL in Lithuanian is morphologized and full of exceptions, the alternations are evident in the spoken language. /n/ is deleted before non-plosives and word-finally. A preceding short V is lengthened by CL:

(8) a. /sʲpʲrʲɛn-dʒa/ → [sʲpʲrʲɛndʒa] ‘sends’
b. /sʲpʲrʲæn-sʲtʲɪ/ → [sʲpʲrʲæːsʲtʲɪ] ‘to send’ (Kavitskaya 2002, p. 61)

(9) /dʲirbʲæn/ → [dʲirbʲæː] ‘having worked’ (*ibid.*)

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[3] Languages in which the reflexes of diachronic processes of CL can be seen include Germanic (Kavitskaya, 2002), Ancient Greek (Wetzels, 1985), and Latin (Kavitskaya, 2002).

Luganda If the first vowel in a Luganda VV sequence is high, it becomes a glide and the second vowel is lengthened. In other words, glide formation both resolves hiatus and triggers CL:

(10) /li-ato/ → [ljaːto] ‘boat’ (Clements 1985, (13))

(11) /a-ba-kulu a-ba-o/ → [abakulwaːbo] ‘those elders’ (*ibid*., (14))

This kind of lengthening also occurs across word boundaries, as in (11). Sequences of identical vowels in Luganda are realized as tautosyllabic long vowels. Together, these facts indicate that the form in (10) is syllabified as /li.a.to/ in the input but as [ljaː.to] in the output. If that is the case, mora count is preserved across the whole form, rather than within a particular syllable (See Kiparsky (2010) for discussion of this point).

In the same language, vowels preceding nasal-stop sequences are lengthened when these sequences become prenasalized stops:

(12) /ba-ntu/ → [baː.ntu] ‘people’ (Clements 1985, (27))

Here we have the added complication that the segment /n/ is lost, but both its mora and its nasality are retained (in the preceding vowel and the following consonant, respectively). The same thing happens in Runyambo, a related Bantu language:

(13) /o-mu-ntu/ → [omuː.ntu] ‘person’ (Kavitskaya 2002, p. 64)

Here, too, the /n/ itself is gone, but its mora and its nasality are retained.

Ngajan In Ngajan, a palatal glide is lost and the preceding V lengthens:[4]

(14) a. /burrubaj/ → [buʀubaː] ‘a boil’
b. /bujbu/ → [biːbu] ‘to spit at’ (Kavitskaya 2002, p. 46)

There are three phonemic vowels in the language (/i/, /a/, and /u/). /ij/ sequences do not exist. When the /j/ deletes, a preceding /a/ is lengthened but remains [a]; a preceding /u/, on the other hand is both lengthened and undergoes a change in quality to [i]. In some cases, then, the front quality of the deleted glide is retained in the newly lengthened vowel.

Coda /r/ and /l/ were also lost in this language, with CL of the preceding V:

(15) a. /ɲamir/ → [ɲamiː] ‘hungry’
b. /bulal/ → [bulaː] ‘firefly’ (Kavitskaya 2002, p. 54)

Persian In colloquial Farsi, /h/ is deleted word-finally without CL. But preconsonantal /h/ is deleted with CL of the preceding V in word-medial and word-final syllables:

(16) /fahmidi/ → [faːmidi] ‘you have understood’

(17) /ʃahr/ → [ʃaːr] ‘city’ (Kavitskaya 2002, p. 70)

In colloquial Tehrani Farsi, /h/ and /ʔ/ are deleted when they occur in codas, by themselves or as either member of a coda cluster.:

(18) a. /ʃoʔbe/ → [ʃoːbe] ‘branch’ (Kavitskaya 2002, p. 82)
b. /roʔb/ → [roːb] ‘terror’ (Darzi 1991, (4b))
c. /robʔ/ → [roːb] ‘quarter’ (*ibid*. (4a))

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[4] In (14), Ngajan is compared with a more conservative dialect. Kavitskaya (2002) does not provide the underlying forms.

If moraicity is related to sonority, it should not be possible for /h/ and /ʔ/ to be the only moraic coda consonants in the language, as claimed by Darzi (1991). This puzzle leads Kavitskaya (2002) to claim that /h/ and /ʔ/ are phonetically realized as approximants. Moreover, because other consonants are deleted in similar contexts without triggering CL, analyses based on trimoraic syllables (Hayes, 1989) or extrasyllabicity of syllable-final consonants are ruled out. If each member of a coda cluster were associated with its own mora and all syllables ending in two-consonant clusters were trimoraic, we would expect the deletion of other consonants to also trigger lengthening. The fact that consonants more sonorant than /h/ or /ʔ/ are deleted from coda clusters without triggering lengthening renders this analysis untenable. Similarly, if final consonants were extrasyllabic and deletion, we would expect all doubly-closed syllables to be bimoraic. Deletion of one coda consonant, no matter its identity, would trigger CL and leave a syllable with a long vowel and a single coda consonant. Again, this is not what happens; only /h/ and /ʔ/ trigger lengthening when they are deleted. It is clear, then, that some other account is needed for the analysis of CL in this dialect. See Section 6.4.3 for a more thorough discussion of this problem.

Turkish Turkish has a number of distinct, productive processes of synchronic CL. While the environments that trigger CL can be difficult to describe, the lengthening itself is exceptionally straightforward. Consonants are deleted from particular environments, regardless of whether they would surface as onsets or codas. Deletion from coda position triggers lengthening, while deletion from onset position does not. In so-called *h*-Deletion, for example, coda /h/ is deleted before continuants or nasal stops, which results in lengthening of the preceding vowel. Onset /h/ is deleted after vowels or voiceless consonants, and lengthening does not occur:

(19) a. /tahsil/ → [taːsil] ‘education’ (Sezer 1985, (8i))
b. /šüphe/ → [šüpe] ‘suspicion’ (*ibid.*, (9ii))

In *y*-Deletion, /j/ is deleted when it occurs between a front vowel and a sonorant consonant or /i/. Lengthening happens before sonorant consonants (where /j/ is a coda) but not before /i/ (where it is an onset):

(20) a. /öjle/ → [öːle] ‘thus’
b. /dejil/ → [deil] ‘is not’ (Sezer 1985, (12i))

Similarly, in *v*-Deletion, /v/ is optionally deleted when followed by a labial consonant or round vowel or when preceded by a round vowel. Lengthening of the previous vowel occurs when the /v/ is a coda but not when v is an onset.

(21) a. /övmek/ → [öːmek] ‘praise-INF’
b. /över/ → [öer] ‘praise-3.AORIST’ (Sezer 1985, (14i))

In all of these cases, the deletion itself does not care about coda (*vs.* onset) position, but the lengthening does: the preceding vowel lengthens only when the deleted consonant would otherwise surface as a coda.

Yet another phenomenon takes place in Western Anatolian dialects, where the loss of coda /r/ causes CL in the preceding V:

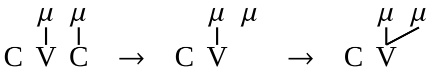
(22) /var/ → [vaː] ‘there is’ (Kavitskaya 2002, p. 55)

3 Previous approaches to the analysis of CL

3.1 Autosegmental analyses

Autosegmental analyses of CL, beginning with Hayes 1989, are derivational and consist of two steps. First, a consonant that was associated with a mora is deleted, leaving the mora unassociated with any segment. In the second step, a rule of reassociation links the floating mora with the preceding vowel, lengthening it. This process is schematized in (23):

(23)



The analysis itself relies on a particular order of operations. The coda consonant is deleted from the segmental tier only, leaving the mora unassociated on another tier. Another rule automatically applies, associating that mora with an adjacent segment. That reassociation rule applies only in one direction, thereby ensuring that the floating mora is linked with the preceding vowel rather than a segment elsewhere in the word or syllable.

The central insight of the autosegmental approach is that CL is analyzed as preservation of mora count. The idea of mora conservation explains the coda/onset asymmetry in CL—only segments that are underlyingly associated with a mora trigger lengthening when they are deleted.

3.2 Phonetic analyses

Kavitskaya (2002) presents a phonetically motivated analysis of CL. Under this phonologization model, vowels are phonetically longer in certain contexts. When consonants are lost in those contexts, the phonetic difference in length is reinterpreted as a phonemic contrast. Triggers of CL, then, are consonants that can be interpreted as part of the vowel or affect its length for some reason. There are three weaknesses of this approach. First, it is not clear why particular consonants should serve as CL triggers in one language when an entirely different set of consonants triggers CL in another. If CL is phonetically motivated in the way the phonologization model proposes, we would expect to see a hierarchy of triggers—if a language has CL triggered by the loss of low-sonority consonants, it should also have lengthening triggered by the loss of glides, for example. We saw in Section 2 that this is not the case and that the set of CL triggers in a given language is highly idiosyncratic. Secondly, this model does not straightforwardly predict a case in which a consonant-final stem has CL if it is followed by a consonant-initial suffix but not when the following morpheme is vowel-initial (*i.e.,* if the stem-final consonant is a coda, but not if it is an onset). In other words, the analysis does not capture the generalization that only moraic segments—*i.e.*, codas—trigger lengthening when they are deleted. It is difficult to see how the CL case could result from reanalysis of a phonetic length contrast, especially if the initial consonant of the following morpheme is similar in sonority to the deleted consonant. Even if she does not understand the process of CL, the speaker presumably knows at some level that there is a stem-final consonant in the form. In short, phonologization is a better model of diachronic change than it is of synchronic CL.

The third weakness in the account is theoretical. If we believe that CL is a productive, synchronic, and intralinguistically predictable process, we should account for it in the same way we account for other productive, synchronic, and predictable processes: in the phonology.

3.3 Classic OT

The autosegmental analysis outlined in Section 3.1 cannot be imported into modern, OT approaches to phonology for two reasons. First, OT is not a derivational framework; the rule ordering required by the autosegmental analysis cannot be incorporated. In the parallel framework advocated by proponents of classic OT, all possible candidates are evaluated at once. There is no way to delete a segment and then lengthen an adjacent segment; instead, the deletion and the lengthening must happen at once. The problem with this parallel evaluation is that the candidate that has both deletion and lengthening violates more faithfulness constraints than a candidate that has deletion but no lengthening (and sometimes more faithfulness violations than a candidate that has lengthening but not deletion). The second problem is that syllabic and moraic structure are not necessarily present in the underlying form in OT. If we wish to maintain the generalization that only moraic segments trigger CL when they are deleted, there must be a way of guaranteeing that the segment that will be deleted is associated with a mora in the input. Because languages do not contrast moraic and non-moraic segments, this is assumed to be impossible in OT due to Richness of the Base (Prince and Smolensky, 1993/2004), a principle that requires all non-contrastive inputs to be considered.

In OT, inputs are not guaranteed to be syllabified. There are two reasons for this underspecification of underlying forms. The first is that in no language is syllable structure contrastive. That is, no language contrasts [ta.pa] with [tap.a]. Second, syllabification is derivable from constraints on general syllable structure and on sonority sequencing, and so can be derived from any underlying moraic specification. The lack of syllabification in underlying forms is particularly relevant for CL. Recall that in canonical CL, it is necessarily a coda consonant that deletes. Onset deletion never triggers CL. But whether a segment is part of an onset or part of a coda cannot be determined until the word has been syllabified. And because only coda consonants (not onsets) are associated with moras, moraic specification cannot be determined until the word has been syllabified.[5]

Furthermore, moraic structure is completely predictable. In a language in which Weight by Position (WBP; Hayes 1989, p. 258) is undominated, all coda consonants are are automatically associated with a mora. Onsets are not. In languages with high-ranking constraints against associating moras with consonants, no non-nuclear segment is associated with a mora. WBP can also be parameterized by sonority, such that coda segments that meet a particular sonority threshold are associated with a mora while segments that have lower sonority are not associated with a mora even when in coda position. The principle of Richness of the Base, then, requires us to consider both inputs with moraic consonants and inputs with non-moraic consonants. In all cases, constraints on syllable wellformedness get the correct moraic structure—any moras associated with onsets in the syllabified form will be removed, while moras will be inserted as necessary to create moraic codas.

What is relevant for the analysis of CL is that it cannot be guaranteed that a particular consonant is associated with a mora in the underlying representation of a word. Because underlying representations may not be syllabified, it is impossible to know whether a given input consonant is part of a coda. And because moras are only assigned to coda consonants, moraic specification cannot be ascertained from the underlying representation alone. This is problematic for the analysis of CL because lengthening is only triggered by deletion of segments that were associated with a mora before they were deleted. Because OT evaluations occur in parallel, there is no formal mechanism to ensure that the correct moraic structure is built before segments are deleted.

To illustrate this point, consider first the effect of two faithfulness constraints on an example from Komi Ižma:

(24) a. MAX[SEG] (MAX): Assign a violation for each segment in the input that is not present in the output.

b. DEP[μ]: Assign a violation for each mora in the output that is not present in the input.

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[5] This is true unless the language has geminate consonants, in which case consonant length (not syllable weight) is contrastive. Geminate consonants are assumed to be associated with a mora in the underlying representation, while singleton consonants are not.

One problem for a classic OT analysis of CL is that two separate processes, incurring two separate faithfulness violations, must occur in the same evaluation. Consider an input in which the consonant that is to be deleted is not associated with a mora. The CL candidate (b)—the one that is supposed to be the winner—is harmonically bounded by a candidate in which deletion but not lengthening occurs, as in (25):[6]

(25) *Harmonic bounding of the CL candidate in parallel OT*

μ μ k ɨ l n ɨ	Max	Dep[μ]
μ μ μ a. ☹ k ɨ n ɨ	*	*
μ μ b. ☞ k ɨ n ɨ	*	

If we assume that the language has an undominated constraint agains having [l] in coda position (call it *l/Coda), there are two ways to avoid violating this constraint—deleting the /l/, or deleting the following consonant and resyllabifying the /l/ as an onset. The candidate that has /l/ as an onset beats any candidates that have /l/ in coda position when the /n/ has been deleted. Because each candidate is syllabified, the winner is the one that is most harmonic according to the language's principles of syllabification. In this case, removing the /l/ from coda position is always the best option. In (25), candidate (b) violates only Max, the constraint that penalizes deletion of segments. Candidate (a), on the other hand, violates both Max and Dep[μ], which penalizes the insertion of moras. As a consequence, (a) will never be chosen over (b) to become the winning candidate. The CL candidate is also harmonically bounded by a candidate in which a segment that should be an onset is deleted:

(26) *More harmonic bounding of the CL candidate in parallel OT*

μ μ k ɨ l n ɨ	Max	Dep[μ]
μ μ μ a. ☹ k ɨ n ɨ	*	*
μ μ b. ☞ k ɨ l i	*	

In (26b), the second member of a two-consonant cluster is deleted and the remaining consonant is syllabified as an onset. Because this candidate violates only Max, it will always beat the CL candidate (which still incurs two faithfulness violations).

Finally, consider an input in which one member of the consonant cluster happens to be associated with a mora, while the other is non-moraic (Remember that Richness of the Base forces us to consider such candidates.):

(27) *CL triggered by onset loss in parallel OT*

μ μ μ k ɨ l n ɨ	Max	Dep-L[μ]	Max-L[μ]
μ μ μ a. k ɨ n ɨ	*	*	*
μ μ μ b. k ɨ l ɨ	*	*	*

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[6] In the tableaux in this paper, vowels are represented as underlyingly moraic. This is done to highlight the relevant contrasts in the moraic specification of consonants, but nothing hinges on this assumption. The same result could be obtained by including an undominated constraint against non-moraic vowels.

MAX-L[μ] and DEP-L[μ] are constraints that penalize the de-linking and re-linking of moras to segments, respectively. I will show later that the definitions of these constraints are contentious; for now, it is enough to note that both of these constraints are violated when a mora is de-associated from one segment and re-associated with another. Notice, then, that lengthening can be triggered by the loss of a coda or by loss of an onset in (27), and there is no way of distinguishing the two by ranking these faithfulness constraints. So there is no way to capture the generalization that CL can only be triggered by loss of a coda (or other moraically specified segment).

Along these lines, Kiparsky (2010) identifies four problems that CL poses for parallel OT, one of which is particularly relevant here. This is the “distinctiveness problem”: There cannot be faithfulness to a mora that is not present in the input. And we cannot guarantee that that mora is present in the input because of Richness of the Base. This is the thorniest problem for OT and, as we will see, HS. Kiparsky provides a good argument for why CL cannot be accounted for in parallel OT, based on two kinds of evidence: (i) CL in Luganda involves resyllabification, and (ii) CL refers to a level of representation at which moras are necessarily distinctive. He does not, however, present an alternative approach. What is clear is that some kind of derivational component is required.

3.4 OT-CC

Shaw (2007) analyzes CL in OT-CC. In that framework, derivations occur in several steps, each one incurring one violation of a faithfulness constraint. Violations may be ordered with respect to one another via PREC constraints. Shaw’s analysis makes crucial use of a PREC constraint that requires violations of MAX to be preceded by violations of DEP[μ]. This ordering is intended to ensure that the correct moraic structure is present before segments are deleted. In other words, a mora must be inserted (and associated with the consonant that is to be deleted) before any segment can be deleted.

Shaw notes that the only way to account for CL in OT-CC is to invoke mora sharing. In other words, CL happens in two steps, but there is never a stage at which a mora is not attached to any segment. Instead, the coda’s mora is first doubly-linked with the lengthened vowel. The coda consonant is deleted in a second step. Shaw’s approach can be schematized as follows:

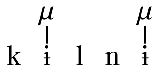
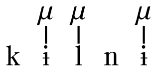
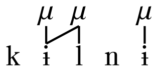
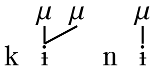
Candidate		→		→		→	
Constraint violated			DEP[μ]		DEP-Link[μ]		MAX

Table 1: Candiate sequence (Shaw, 2007)

This analysis runs up against at least two problems. First, it predicts that, in any language with CL, there can be no deletion of other, non-moraic segments. Nor can there be deletion of moraic segments that does not trigger CL. This prediction is not borne out; there are languages (like Turkish; see Section 2) in which deletion of a consonant from coda position triggers CL, while deletion of the same segment from onset position does not trigger CL. The second problem is that the analysis is not consistent with Richness of the Base, which is a fundamental principle of Optimality Theoretic analyses. I reserve a detailed discussion of Richness of the Base for Section 3.3; for now it is sufficient to note that it requires us to consider inputs with both moraic and non-moraic segments. Shaw’s analysis, on the other hand, considers only non-moraic inputs. If the consonant that is to be deleted were underlyingly associated with a mora, DEP[μ] would not be violated by the insertion of a mora. That in turn would mean that no violations of MAX could occur because any deletion of a segment would not be preceded by insertion of a mora as the PREC constraint requires.

Given that Richness of the Base is a fundamental principle of constraint-based phonology, this is a severe limitation of the analysis.

4 Problems for Harmonic Serialism

4.1 Harmonic Serialism

HS is essentially a derivational variant of classic OT. The input makes multiple passes through the same constraint ranking, with the winning candidate of each pass serving as the input to the following stage until the faithful candidate wins and the derivation converges. Unlike in classic OT, however, each candidate in a HS derivation may incur at most one faithfulness violation.[7] This is gradualness—the idea that the derivation proceeds in many small steps. Each of these steps is pronounceable and is potentially a surface form in some language that has a different constraint ranking: "[I]f one language has the mapping A → B → C, then another will have the mapping A → B (where B is the ultimate output)" (McCarthy, 2000; p. 20).

Despite its inherently derivational nature, HS is not naturally well suited to an analysis of CL. CL is a type of counterbleeding opacity—a mora is associated with a different segment on the surface from the one it was associated with at some previous level of representation—and "wherever classic OT has a problem with counterbleeding opacity, harmonic serialism will too, since harmonic serialism is just classic OT, iterated" (McCarthy 2007, p. 37).

At the same time, the derivational component of HS is well suited to the analysis of segmental phenomena that make reference to metrical structure. McCarthy's (2008b) analysis of syncope, for example, makes use of an "intrinsic ordering" of building metrical structure before segments are deleted, and that ordering seems relevant to CL as well. But the account relies on EXHAUSTIVITY, which effectively prohibits one level of prosodic structure from being built before the level below it is present in the input. This works for prosodic structures like feet—a metrical word node can't be introduced until foot structure is present in the input. The problem is that CL refers only to syllable structure, and it is difficult to see how this approach would generalize. Syllables are automatically introduced at every step in the derivation, and moraic structure crucially relies on syllabification (for coda consonants to satisfy WBP, at least). It is not the case that the higher prosodic category (the syllable) is introduced dependent on the category it dominates (the mora), as it is for elements higher in the prosodic hierarchy. For this reason, it is not immediately clear how HS can answer the question of how to ensure that moras are assigned before deletion takes place. It is clear that we need some additional mechanism to guarantee that prosodic structure is built before segments are deleted. First, let us consider how gradualism is implemented in HS.

Gradualism Gradualism—the idea that the output of any given step in the derivation can incur at most one faithfulness violation—is a central tenet of HS. While this requirement has been relaxed somewhat in more recent implementations of HS in favor of operational definitions of gradualism (Pruitt 2010, *i.a.*), this body of work is mostly concerned with metrical structure and the operational approach does not easily generalize to phenomena like CL that refer to both segmental and prosodic phonology. For that reason, I will use the faithfulness-violation-based definition of gradualism. The remainder of this section is devoted to exploring the implications of gradualism for the analysis of CL.

One relevant consequence of gradualness is that the deletion of a consonant can be interpreted as proceeding in at least two steps: deletion of any associated place features, then deletion of the consonant itself (McCarthy, 2008a). This process raises a number of interesting questions. There must be a stage in the derivation where the coda consonant is placeless but still moraic. Are there languages that stop at

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[7] In the strictest interpretation of HS (and the one which was originally intended), faithfulness violations are always evaluated with respect to the input to the first pass. To maximize the clarity of tableaux, I will evaluate violations with respect to the input to the current stage. This decision is in accord with recent HS analyses.

this stage? In other words, are there languages that have placeless moraic consonants which are derived from underlying moraic consonants that have their own place features? How is the pronunciation of these placeless consonants different from the pronunciation of underlyingly placeless consonants like /h/ and /ʔ/? These questions will be explored in more detail in Section 5.3.

Furthermore, it is not entirely clear how this gradual approach to deletion generalizes to the association between segments and moras; in CL, the segment should be deleted while leaving the mora in place. Gradualness becomes much more difficult to define when we consider both segmental and moraic faithfulness constraints. Citing Campos-Astorkiza (2004), McCarthy claims that "MAX[μ] does not apply to the moras associated with non-geminate codas" (McCarthy 2008a, p. 290). In other words, for McCarthy, deleting a mora associated with a coda consonant does not constitute its own derivational step. As I will show in the next section, treating constraints on the insertion and deletion of moras as something other than faithfulness constraints raises a number of theoretical concerns, but is ultimately a good idea.

Setting those concerns aside for the moment, the output of each pass after the first, fully faithful step must incur at most one violation of (a single) basic faithfulness constraint. Basic faithfulness constraints are limited to MAX[x], DEP[x], IDENT[f], and LINEARITY. In this sense, Gradualness has particular consequences for prosodic structure:

> In HS, [. . .] any step in a derivation that introduces the word level of constituency must also introduce the foot level [. . .]. This is entirely in line with the gradualness requirement, because assigning word constituency brings with it no violations of any basic faithfulness constraints, besides those incurred by concomitant foot assignment. (McCarthy 2008b, p. 509)

If we extrapolate to other levels of prosodic structure, this means that any step that introduces the syllable level must also introduce moraic structure. This is acceptable because assigning syllabic constituency brings with it no violations of any basic faithfulness constraints besides those incurred by concomitant mora assignment. Further, because the output of every step in the derivation is syllabified, moraic structure must be present in all outputs. At first glance, this looks promising for an analysis of CL because it seems to imply that moraic structure must be built before, for example, deletion of segments may occur. But moras have a dual status that hinders a straightforward analysis with respect to faithfulness constraints:

> Quantity and syllabicity are matters of faithfulness, since they are both contrastive in some languages, but weight by position is probably not, since the weight of codas never seems to be contrastive within a language [. . .]. It follows that changing a segment's quantity or syllabicity is a [basic faithfulness violation], but, say, resyllabifying a moraic coda as a nonmoraic onset is not. (McCarthy 2007, p. 76)

This dual status raises some theoretical concerns for a HS analysis of CL. Before discussing some of the relevant constraints, I turn to a preliminary analysis.

Fully Faithful Candidates At first glance, the concept of the FFC—introduced by McCarthy (2007) for OT-CC, but equally applicable to HS—can help in ensuring that moraic structure is built before any deletion or lengthening applies. The FFC is the first step in any derivation, and it must be a candidate that violates no basic faithfulness constraints. It can differ from the input in properties that are not subject to faithfulness constraints; practically, this usually amounts to a syllabified version of the input. The next subsection discusses the issues involved in determining this FFC in some detail.

4.2 A schematic analysis

Suppose we start with a /CVC/ input. Suppose further that this particular input contains a non-moraic final C. If the language has CL, the first step in the derivation will necessarily be to ensure that the final C is assigned a mora. What will this look like under the assumption that we begin with a fully faithful first input?

The following constraints will be relevant for the derivation:

(28) *Relevant constraints for a HS analysis of CL*

a. WBP
Assign a violation for each coda consonant that is not dominated by a mora.

b. Max[μ]
Assign a violation for each mora in the input that is not present in the output.

c. Max
Assign a violation for each segment in the input that is not present in the output.

d. NoCoda
Assign a violation for every syllable in the output that has a segment in its coda.

e. *μ/C (following Broselow et al. (1997))
Assign a violation for each mora that does not dominate a vowel in the output.

f. Dep[μ]
Assign a violation for each mora in the output that is not present in the input.

Given these constraints, the first step will look something like the following:

(29) *Determining the FFC for a /CVC/ input*

$C\overset{\mu}{V}C$	WBP	Max[μ]	Max	NoCoda	*μ/C	Dep[μ]
a. $C\overset{\mu}{V}C$	*		*			
b. $C\overset{\mu}{V}\overset{\mu}{C}$			*		*	*

Keeping in mind that a FFC is a candidate that incurs no faithfulness violations, there are two possible FFCs for the input given above. I will consider each of them in turn.

4.2.1 [CV$^{\mu}$C] as a FFC

Suppose that [CV$^{\mu}$C], a form that is uncontroversially fully faithful to the input /CVC/, is the winning FFC. If CL is to occur, we still need to assign a mora to the final consonant:

(30) *First iteration: Assigning a mora to the coda consonant*

$C\overset{\mu}{V}C$	WBP	Max[μ]	Max	NoCoda	*μ/C	Dep[μ]
a. $C\overset{\mu}{V}C$	*!			*		
b. $C\overset{\mu}{V}$			*!			
c. ☞ $C\overset{\mu}{V}\overset{\mu}{C}$				*	*	*

For the form with a moraic coda to be the winner at this step, WBP and Max must dominate NoCoda (as well as Dep[μ] and *μ/C). Here we have a ranking paradox. We want the consonant that will eventually be deleted to remain in the representation long enough to be associated with a mora. For that to happen, Max must be ranked above NoCoda. But we want that consonant to be deleted at some point in the derivation. If the consonant is to delete at all, NoCoda must be ranked above Max (Of course, we would also need a constraint like Dep-L[μ] to distinguish between the second and third candidates.). Otherwise, the constraint that motivates deletion is ranked below the constraint that penalizes deletion, which means that deleting the coda consonant will never be harmonically improving:[8]

(31) *Second iteration: A ranking paradox prevents the coda from deleting*

μ μ C V C	WBP	Max[μ]	Max	NoCoda	*μ/C	Dep-L[μ]
μ μ a. ☞ C V C				*	*	
μ b. C V		*!	*			
μ μ c. ☹ C V C			*!			*

OT-CC could potentially solve this problem with a Prec constraint that requires violations of Max to be preceded by violations of Dep[μ] (see Shaw 2007), but problems arise from this strategy. First, such a constraint would only work if the consonant could be guaranteed to be non-moraic in the input. Richness of the Base says this is not necessarily the case. We must consider forms that have a mora associated with the coda consonant in the input. In those cases, there is no need to insert a mora and therefore no need to violate Dep[μ] at all. If the constraint is not violated, the Prec constraint does not allow Max to be violated, meaning that the consonant could never be deleted. Furthermore, such an analysis predicts that no language will have CL triggered by deletion of (part of) a geminate consonant (which, under standard assumptions, would be underlyingly moraic). In this case, too, the segment is underlyingly associated with a mora and the derivation would proceed without violating Dep[μ] at all. Finally, HS does not have the option of using a Prec constraint. To summarize, if [CV^{μ}C] is the FFC from the input /CVC/, HS faces a ranking paradox.

4.2.2 [$\text{CV}^{\mu}\text{C}^{\mu}$] as a FFC

The analysis faces some additional challenges if [$\text{CV}^{\mu}\text{C}^{\mu}$] is the FFC. If, as mentioned in the previous section, inserting moras to satisfy WBP does not violate any faithfulness constraints, it is possible that [$\text{CV}^{\mu}\text{C}^{\mu}$] could serve as the input to first step in the derivation. This would eliminate the ranking paradox—we would not need Max to dominate NoCoda, and the ranking NoCoda ≫ Max could hold through the deletion of the coda consonant:

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[8] Here and in the analysis to follow, I abstract away from the idea that consonant deletion must occur in at least two steps to satisfy the gradualness requirement.

(32) *First iteration: Deleting the coda consonant*

$\text{C}\,\overset{\mu}{\text{V}}\,\overset{\mu}{\text{C}}$	WBP	Max[μ]	NoCoda	Max	*μ/C	Dep[μ]
a. $\text{C}\,\overset{\mu}{\text{V}}\,\overset{\mu}{\text{C}}$			*!		*	
b. $\text{C}\,\overset{\mu}{\text{V}}$		*!		*		
c. ☞ $\text{C}\,\overset{\mu}{\text{V}}\;\mu$				*		

Notice, though, that [$\text{CV}^{\mu}\text{C}^{\mu}$] violates the constraint Dep[μ] (see (29)). It must be the case, then, that Dep[μ] is not a relevant faithfulness constraint, at least when the mora is inserted to satisfy WBP. This is McCarthy's (2008a) stance on Max[μ]. But Max[μ] is absolutely crucial to an analysis of CL as mora conservation. There must be some penalty for violating it—otherwise, languages with non-geminate codas could never have CL. If building moraic structure is not the kind of change that incurs faithfulness violations, there will never be any motivation to preserve that structure. Unless the constraints are redefined so that they are violated only in certain circumstances, this is a major problem for the theory.

If adding moraic structure to an input is acceptable in arriving at a FFC, we run into contradictory assumptions about the nature of the constraint set and when those constraints can be violated. One possible solution would be to not take Richness of the Base at face value. However, it is not possible to ensure that coda consonants are assigned moras in the input if the input is not syllabified, and assuming syllabification in the underlying representation runs counter to the central principles of OT and HS. Adding syllabification to underlying representations would be undesirable for several reasons. Syllabification is non-contrastive; if we can derive it from independently-motivated constraints, it is unnecessary and redundant to include it in the underlying representation. Furthermore, every possible form (*i.e.*, every possible combination of morphemes in the language) would have to be listed in the lexicon with its own syllabification. This would be unwieldy to say the least for agglutinative languages; if we maintain the assumption that syllabification is a constraint-driven process that occurs only after the relevant morphemes have been selected, the lexicon remains a much more manageable size. It may be more fruitful to consider redefining the problematic constraints instead. This is the approach I take in the next section.

4.3 Constraints

4.3.1 Dep[μ]

Campos-Astorkiza (2004) defines a "positional μ-licenser" in the following way:

(33) Let μ be a mora and α be a segment, μ is a positional μ-licenser of α, iff μ is the only prosodic unit immediately dominating α.

In other words, a positional mora is a mora that satisfies WBP:[9] Moras that indicate vowel length are not positional moras because two moras dominate the long vowel, and moras that indicate geminate consonants are not positional moras because the consonant is dominated by a mora in the coda of one syllable and by the syllable node in the following syllable. The constraint P(ositional)-Dep[μ] is defined in the following way:

(34) P-Dep[μ]:
A non-positional μ-licenser mora in S_2 has a correspondent in S_1. (Campos-Astorkiza 2004, (20))

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[9] Or a mora that is inserted to be associated with a vowel that happens not to be moraic in the input.

This means that, for example, inserting a mora because an onset consonant is resyllabified as a coda, does not incur a violation. The constraint penalizes only the insertion of moras that change length.

P-Dep[μ] is not without its problems, however. The constraint does not penalize the insertion of a mora that exclusively dominates an initial consonant (35a) or of moras that dominate each member of a complex coda (35b):

(35) a. t $\overset{\mu}{\text{a}}$ t → $\overset{\mu}{\text{t}}$ $\overset{\mu}{\text{a}}$ t

b. t $\overset{\mu}{\text{a}}$ n s t → t $\overset{\mu}{\text{a}}$ $\overset{\mu}{\text{n}}$ $\overset{\mu}{\text{s}}$ $\overset{\mu}{\text{t}}$

If WBP and related constraints are high-ranking enough, though, the exact definition of the constraint will not matter—a constraint that penalizes moras associated with onset consonants should rule out (35a), while a constraint that penalizes syllables containing more than two moras would rule out (35b).

This type of constraint does appear to solve the fully faithful candidate problem. If inserting a mora to satisfy WBP is not a faithfulness violation, a candidate with a moraic coda consonant will be the input to the first step in a HS derivation, regardless of whether that mora is present in the underlying form. Returning to a hypothetical example, it is clear that this is possible only if we use P-Dep[μ] instead of Dep[μ]. (36) shows that the insertion of a mora associated with a coda consonant violates Dep[μ] but not P-Dep[μ]. Because the FFC must be a candidate that violates no basic faithfulness constraints, this contrast provides evidence for the claim that it is P-Dep[μ], not Dep[μ], that is a basic faithfulness constraint.

(36) *Inserting moras associated with coda consonants does not violate P-*Dep*[μ]*

C $\overset{\mu}{\text{V}}$ C	Dep[μ]	P-Dep[μ]
a. C $\overset{\mu}{\text{V}}$ C		
b. ☞ C $\overset{\mu}{\text{V}}$ $\overset{\mu}{\text{C}}$	*	

P-Dep[μ] would help eliminate the Max/NoCoda ranking paradox; if it can be guaranteed that a form with a moraic coda is the FFC, regardless of the moraic specification of the input, Max need not dominate NoCoda.

Campos-Astorkiza (2004) does not discuss P-Max[μ], but we would expect it to be a (useful) constraint—it would be strange to have P-Dep[μ] but not Dep[μ] on the one hand and Max[μ] but not P-Max[μ] on the other. Furthermore, if P-Dep[μ] is formulated so as to ensure that non-moraic inputs satisfy WBP without violating any basic faithfulness constraints, P-Max[μ] ought to be used to ensure that moraic inputs correspond to non-moraic FFCs in languages that do not have high-ranking WBP. In Campos-Astorkiza 2004, part of the justification for redefining Dep[μ] comes from the fact that the accepted version of the constraint predicts an unattested variability in coda weight depending on whether or not the input happens to be moraic. In (37b) and (38b) (Campos-Astorkiza's (5b) and (6b)), we see that ranking Dep[μ] above WBP incorrectly predicts the existence of a language in which coda consonants are moraic if and only if they are moraic in the input. The prediction directly contradicts the assumption that segments may be moraic or non-moraic in the input, with their eventual moraic specification dependent only on their position within the syllable.

(37) For a non-moraic input:

a. WBP ≫ Dep[μ]: /CVC/ → [CVC$^{\mu}$]

b. Dep[μ] ≫ WBP: /CVC/ → **[CVC]**

(38) For a moraic input:

a. WBP ≫ Dep[μ]: /CVC$^{\mu}$/ → [CVC$^{\mu}$]

b. Dep[μ] ≫ WBP: /CVC$^{\mu}$/ → **[CVC$^{\mu}$]**

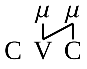
A similarly problematic prediction can be made for Max[μ]. Here, the other relevant constraint is not WBP but *μ/C, which penalizes moras that are headed by consonants. In this case, ranking Max[μ] above *μ/C again predicts the existence of a language in which coda consonants are moraic if and only if the corresponding segment is moraic in the input:

(39) For a non-moraic input:
  a. *μ/C ≫ Max[μ]: /CVC/ → [CVC]
  b. Max[μ] ≫ *μ/C: /CVC/ → **[CVC]**

(40) For a moraic input:
  a. *μ/C ≫ Max[μ]: /CVC$^{\mu}$/ → [CVC]
  b. Max[μ] ≫ *μ/C: /CVC$^{\mu}$/ → **[CVC$^{\mu}$]**

That said, P-Max[μ] cannot be the relevant constraint for the analysis of CL. While it should be possible to delete moras that are unnecessarily associated with segments in the underlying representation, once those moras are appropriately associated with coda consonants, CL cannot proceed unless those moras are preserved. In particular, the derivation falters if the coda consonant and the mora associated with it can be deleted at once. Because the mora associated with the coda consonant is a positional mora, P-Max[μ] does not penalize its deletion. This means that both the consonant and its mora can be deleted in the same step, violating only Max. This would mean that it would always be better to delete the consonant and its mora than to keep the consonant and its mora with the preceding vowel:

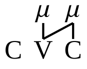
(41)

C $\overset{\mu}{\text{V}}$ $\overset{\mu}{\text{C}}$	WBP	P-Max[μ]	NoCoda	Max	*μ/C	Dep-L[μ]
a. C $\overset{\mu}{\text{V}}$ $\overset{\mu}{\text{C}}$			*!		*	
b. ☞ C $\overset{\mu}{\text{V}}$				*		
c. ☹ 			*!			*

In (41), candidate (b) is the winner because the coda has been deleted, alleviating the violation of NoCoda that is incurred by each of the other two candidates. Candidate (b) violates only the lower-ranked Max, which means that the winning candidate is one that has deletion but no lengthening. The intended winner is candidate (c), in which the mora is shard between the coda consonant and the preceding vowel. With (c) as the input, the next step in the derivation would delete the consonant, leaving a long vowel.

Notice, though, that candidate (b) *is* ruled out by Max[μ]. The traditional version of the constraint penalizes the deletion of all moras, not just those that are associated with the length of a segment. It is clear that Max[μ] is the constraint required for the analysis of CL because the mora associated with the deleted consonant is a positional mora in the input but becomes a non-positional (timing) mora over the course of the derivation. Furthermore, if Max[μ], rather than its positional variant, is a faithfulness constraint, candidate (b) above would not even be considered in a gradual derivation because it violates both Max[μ] and Max. If Max[μ] is used, the relevant candidate is one in which the mora, but not the associated consonant, has been deleted. That candidate is ruled out by undominated WBP:

(42)

C $\overset{\mu}{\text{V}}$ $\overset{\mu}{\text{C}}$	WBP	P-Max[μ]	NoCoda	Max	*μ/C	Dep-L[μ]
a. C $\overset{\mu}{\text{V}}$ $\overset{\mu}{\text{C}}$			*		*!	
b. C $\overset{\mu}{\text{V}}$ C	*!			*		
c. ☞ 			*			*

Using MAX[μ] rather than P-MAX[μ] prevents a mora from being deleted when the coda consonant with which it is associated is deleted. This is because deleting both the mora and the segment runs afoul of gradualness only if the deletion of all moras, not just those that change a segment's length, is penalized. Otherwise, we would not be able to derive CL—it would always be better to satisfy NOCODA by deleting both the mora and the consonant. In what follows, then, I will assume that MAX[μ] is the high-ranking constraint that penalizes deletion of moras. Doing so leaves two questions unanswered. First, how do we reconcile the fact that MAX[μ] makes incorrect predictions with respect to moras that happen to be present in the underlying representation with the fact that the same constraint is indispensable for the analysis of CL? Second, how do we account for deletion of coda consonants that does not result in lengthening? If MAX[μ] requires all moras in the input to be present in the output, we make the incorrect prediction that a mora associated with a coda consonant will remain every time that coda is deleted or resyllabified as an onset. It is possible that these questions could be addressed with yet another formulation of MAX[μ], but I leave that suggestion as an area for future research.

4.3.2 Link constraints

DEPLINK(μ) and MAXLINK(μ) are first proposed in Morén 2001, where they are formulated as follows:

(43) **DEPLINK-MORA[SEG]**—let ζ_j be segments, S_k phonological representations,
S_1 *R* S_2,
ζ_1 is an element of S_1,
ζ_2 is an element of S_2.
ζ_1 *R* ζ_2, and
ζ_2 belongs to a specific sonority class of segments,
if ζ_2 is associated with a mora,
then ζ_1 is associated with a mora. (Morén 2001, p. 28)

(44) **MAXLINK-MORA[SEG]**—let ζ_j be segments, S_k phonological representations,
S_1 *R* S_2,
ζ_1 is an element of S_1,
ζ_2 is an element of S_2.
ζ_1 *R* ζ_2, and
ζ_2 belongs to a specific sonority class of segments,
if ζ_1 is associated with a mora,
then ζ_2 is associated with a mora. (Morén 2001, p. 27)

The constraints in (43) and (44) make no reference to links as objects. They simply require that segments that are linked to a mora in the input should be linked to a mora in the output (or *vice versa*).

The idea is that these constraints are required in addition to DEP[μ] and MAX[μ] allows for reassociation of moras in CL but prevents moras from reassociating at random. The tableau in (45) shows that DEP[μ] and MAX[μ] do not penalize the reassociation of moras and cannot by themselves distinguish between candidates (b) and (c). (c) is selected as the winning candidate only when DEP-L[μ] and MAX-L[μ] are included in the constraint set:

(45) Dep*[μ] and* Max*[μ] do not prevent reassociation of moras*

$\overset{\mu}{\text{V}}$ C	DepLink-μ[C]	MaxLink-μ[V]	Dep[μ]	Max[μ]
a. V C		*		*
b. V $\overset{\mu}{\text{C}}$	*	*		
c. ☞ $\overset{\mu}{\text{V}}$ C				

It is unclear how these constraints can translate from parallel OT to HS—inserting a mora still conflicts with gradualness by violating both Dep[μ] and Dep-L[μ] as formulated here. Two solutions to this gradualness problem are immediately apparent. The first is to reject the strict formulation of gradualism and allow the output of a single pass through the derivation to violate two related faithfulness constraints. While this approach is certainly possible, it would require redefining a central tenet of HS. It is true that recent work in HS has reinterpreted the gradualness requirement, but a more promising avenue for out purposes is to redefine Dep-L[μ] so that it is not violated when Dep[μ] is; that is, so that no violations of Dep-L[μ] are incurred when a mora is inserted:

(46) Dep-L[μ] (revised version):
Given a segment ζ_1 and a mora μ_1 in the input, assign a violation if μ_1 is associated with ζ_1 in the output but not in the input.

(47) Max-L[μ] (revised version):
Given a segment ζ_1 and a mora μ_1 in the output, assign a violation if μ_1 is associated with ζ_1 in the input but not in the output.

(46) prevents a particular mora and a particular segment that are present but unlinked in the input to be unlinked in the output. It is not violated if a mora is inserted.[10] (47) requires that, if a particular mora and a particular segment are linked in the input and both are present in the output, they should also be associated in the output. The constraint is not violated if the segment or the mora is deleted.

This redefinition is necessary given the gradualness requirement of HS. If we were not allowed to link a newly inserted mora with a segment, it would be necessary to go through an intermediate stage that contains a floating mora. Moras, though, are not pronounceable unless they are associated with a segment. Floating moras are a problem for HS given that the intermediate representations must be a possible output in some language. Floating moras are not valid surface representations, so they should be disallowed by Gen. Even if Gen does not generate candidates that have floating moras, there must still be a way to insert moras. The only way to insert a mora without creating a floating mora is to associate that mora with a segment immediately. The relevant constraints, then, must be redefined so that this is possible. Given a constraint set that is fully consistent with the principles of HS, I now turn to an analysis of CL.

5 Compensatory lengthening with gradual deletion

5.1 Gradual deletion

McCarthy (2008a) presents a HS theory of consonant deletion in which the segment is deleted in two stages. First, the consonant's place node is deleted, creating a placeless consonant. In a subsequent step of the derivation, the root node is deleted, removing the consonant from the representation entirely. This

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[10] Thanks to Oliver Northrup for helpful discussion of this point.

idea of gradual deletion grows out of a controversy over whether place features should be governed by an Ident[Place] constraint or by Max[Place] and Dep[Place]—in other words, over whether a place feature is an attribute of a segment (in which case Ident[Place] is appropriate) or an entity of its own that is autosegmentally linked to the consonant itself. In the latter case, Max[Place] and Dep[Place] are the appropriate constraints. These two options have consequences for the process behind consonant deletion. If the relevant constraint is Ident[Place], consonants can be deleted in one step, even in a framework constrained by gradualness. Deletion violates only Max[Segment]; Ident[Place] has no effect. If, on the other hand, place features are entities in themselves, deletion must take place in two stages. In one, the place node is deleted, incurring a violation of Max[Place]. In a later derivational step, the consonant itself is deleted, incurring a violation of Max[Segment].

(48) Max[Place]
Let *input Place tier* = $p_1p_2p_3\ldots p_m$ and *output Place tier* = $P_1P_2P_3\ldots P_m$. Assign one violation mark for every p_x that has no correspondent P_y. (McCarthy 2008a (4))

Max[Place], as defined in (48), has a particular benefit for the analysis of the phenomena with which McCarthy is concerned. Cross-linguistically, intervocalic biconsonantal clusters are simplified either via deletion or via nasal assimilation. In both cases, it is the first consonant, the one in coda position, that is affected. No language systematically simplifies these clusters by deleting the onset consonant. This tendency cannot be straightforwardly explained if a consonant can be deleted in a single step. Much as we saw in the failed analysis of CL, there is no way of distinguishing between a candidate in which the first consonant is deleted and one in which the second consonant is deleted. If, on the other hand, deletion is a two-step process, CodaCond ensures that it will be the coda consonant that loses its place feature, thus allowing the consonant to be deleted in a later step.

(49) a. CodaCond
Assign one violation mark for every token of Place that is not associated with a segment in the syllable onset. (McCarthy 2008a (6))

b. HavePlace
Assign one violation mark for every segment that has no Place specification. (*Ibid.* (8))

Using the constraints in (48) and (49), it can be guaranteed that the coda consonant, but not the onset, deletes. This contrast is illustrated in (50a) and (50b) below (McCarthy's (9) and (12)):

(50) a. *Harmonic improvement in* <pat.ka, paH.ka, pa.ka>

/patka/	CodaCond	HavePlace	Max[Place]	Max
a. pat.ka *is less harmonic than*	*!			
b. paH.ka *is less harmonic than*		*!	*	
c. pa.ka			*	*

b. *Harmonic bounding of* <pat.ka, pat.Ha>

/patka/	CodaCond	HavePlace	Max[Place]	Max
a. pat.ka *is* ***more*** *harmonic than*	*			
b. pat.H	*	*	*	

Gradual deletion allows us to capture the asymmetry between codas and onsets. While underlying representations are not syllabified, the output of the first step of the derivation is. And because the consonant is deleted in two steps with deletion of the place feature occurring first, the output of the first step is a syllabified form with the same segmental makeup as the input. In other words, gradual deletion guarantees that the intermediate representations are syllabified before deletion of segments takes place. This in turn allows us to make distinctions between onsets and codas that are not possible when syllabification and deletion happen within a single pass through the constraint ranking.

This coda/onset asymmetry is also a property of CL—deletion of segments from coda position can trigger lengthening, while deletion of segments from onset position never does. It seems, then, that the analysis of CL might benefit from incorporating gradual deletion. As we will see, gradual deletion appears to be a promising strategy for deriving CL in HS; there is, however, a large class of lengthening that is impossible to account for under a gradual deletion approach.

5.2 Komi Ižma CL with gradual deletion

The immediate appeal of the gradual approach to the deletion of consonants is that it appears to eliminate the MAX/NOCODA ranking paradox that made the previous attempt at a HS analysis untenable. Because it takes at least two derivational steps to delete the coda consonant, it will not be possible to delete that segment before it can be associated with a mora. When the consonant loses its place feature, a placeless consonant remains. Because coda consonants must be moraic in any language that has CL, WBP will require the placeless consonant in the intermediate representation to be associated with a mora. In general, it must be the case that:

(51) C $\overset{\mu\ \mu}{\text{V}}$ is more harmonic than C $\overset{\mu}{\text{V}}$ $\overset{\mu}{\text{H}}$, which is more harmonic than both C $\overset{\mu}{\text{V}}$ C and C $\overset{\mu}{\text{V}}$ $\overset{\mu}{\text{C}}$.

The schema in (51) guides the shape of the derivation and, therefore, the constraint ranking. Given an input of the form $\text{CV}^{\mu}\text{C}^{\mu}$ or CV^{μ}C, the output of the first pass through the constraint ranking must be a form with a placeless, moraic coda consonant ($\text{CV}^{\mu}\text{H}^{\mu}$). Before the ultimate output, $\text{CV}^{\mu\mu}$, there must be an intermediate stage in which the mora associated with the placeless coda consonant is shared with the preceding vowel. When the form with the shared mora serves as the input to the next step, the coda consonant is deleted altogether, leaving a form with a long vowel and no coda.

Recall that, if we assume that P-DEP[μ] is the relevant basic faithfulness constraint, inserting a mora does not constitute a derivational step on its own. This means that inserting a mora and deleting the place features of a consonant can occur simultaneously: CV^{μ}C can become $\text{CV}^{\mu}\text{H}^{\mu}$ in a single pass through the constraint ranking. And because inserting the mora is not a step in itself, the output of the first step of the derivation is $\text{CV}^{\mu}\text{H}^{\mu}$ regardless of whether the input is CV^{μ}C or $\text{CV}^{\mu}\text{C}^{\mu}$.

For concreteness, I return to the familiar Komi Ižma example. As long as *l/CODA and WBP both dominate MAX[place], the most harmonic candidate will be one with a placeless moraic coda consonant. This is illustrated in (52) for an input with a non-moraic /l/ and in (53) for an input with a moraic /l/.

(52) *First iteration: Mora assignment and deletion of place node*

k $\overset{\mu}{\text{ɨ}}$ l n $\overset{\mu}{\text{ɨ}}$	WBP	*l/CODA	MAX[Place]
a. k $\overset{\mu}{\text{ɨ}}$ l n $\overset{\mu}{\text{ɨ}}$	*!	*	
b. k $\overset{\mu}{\text{ɨ}}$ $\overset{\mu}{\text{l}}$ n $\overset{\mu}{\text{ɨ}}$		*!	
c. ☞ k $\overset{\mu}{\text{ɨ}}$ $\overset{\mu}{\text{H}}$ n $\overset{\mu}{\text{ɨ}}$			*

(53) *First iteration: Deletion of place node*

μ μ μ k ɨ l n ɨ	WBP	*l/Coda	Max[Place]
μ μ μ a. k ɨ l n ɨ		*!	
μ μ b. k ɨ l n ɨ	*!	*	
μ μ μ c. ☞ k ɨ H n ɨ			*

In (52), the faithful candidate (a) loses because it violates WBP and *l/Coda. The candidate that retains the place features of the coda consonant (b) is ruled out by *l/Coda. This makes candidate (c), which contains a placeless moraic coda consonant, the input to the next step in the derivation. Crucially, candidates like /kɨnɨ/ are not considered. That candidate cannot be derived from the input in a single step as it incurs two separate faithfulness violations—one for deletion of the consonant's place feature and another for deletion of the consonant itself.[11]

The process is similar for an input with a moraic coda consonant. This time, it is the faithful candidate (53a) that is ruled out by *l/Coda. The form with a non-moraic coda consonant (b) is eliminated by WBP, and the winner is again the form that contains a placeless, moraic coda consonant. Here, too, /kɨnɨ/ is not considered because that candidate violates several faithfulness constraints—Max[Place], Max, and Max[μ].

Considering only the first step in the derivation, we have already seen the advantage of gradual deletion: The output of the first step is the same regardless of whether the input happens to contain a moraic /l/ or not, and there is no danger of the desired, moraically specified form being beaten by a candidate from which the coda consonant has been deleted. The rest of the derivation, then, proceeds as expected. The output of the second pass through the constraint ranking is a form in which a mora is shared between the placeless consonant and the preceding vowel, as illustrated in (54).

(54) *Second iteration: Mora sharing*

μ μ μ k ɨ H n ɨ	WBP	*l/Coda	Max[Place]	*μ/C	*Share	Dep-L[μ]
μ μ μ a. k ɨ H n ɨ				*!		
μ μ μ b. ☞ k ɨ H n ɨ					*	*

Here, the faithful candidate is ruled out by *μ/C, which penalizes moras that exclusively dominate a consonant. That constraint dominates both *Share and Dep-L[μ], so the winning candidate is (54b), in which the mora associated with the consonant is simultaneously associated with the preceding vowel.

Notice that a number of logically possible candidates are not considered in (54) for theoretical reasons. /kɨ$^{\mu}$Hnɨ$^{\mu}$/ is not considered because deleting the positional mora does not constitute a derivational step (Such a candidate would also be ruled out by WBP.). A candidate like /kɨ$^{\mu}$nɨ$^{\mu}$+μ/, in which the placeless consonant has been deleted with a floating mora left behind, is ruled out because floating moras are assumed to be disallowed by Gen. The candidate /kɨ$^{\mu}$nɨ/ violates gradualness because both the coda consonant and

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[11] There is another logically possible candidate in (52): one in which the consonant has been deleted, leaving a floating place feature. Whether floating place features are allowed by Gen is a question that is beyond the scope of this paper. In any case, deleting the consonant but leaving its place feature unassociated will not get result in CL unless that consonant's mora is also unassociated. These forms can either be ruled out by a restriction against intermediate representations with floating features/moras in Gen, or by highly-ranked constraints that preclude floating features and moras.

its associated mora have been deleted. And in /kɨ$^{\mu\mu}$ni/, both reassociation of the mora from the consonant to the vowel and deletion of the coda consonant have occurred, also running afoul of gradualness. Again, the crucial ranking for this step is *μ/C ≫ *Share, Dep-L[μ]. As long as the mora is associated with only the coda consonant, that consonant cannot be deleted without violating gradualness.

In the last step, the placeless coda consonant is deleted, leaving a long vowel. This deletion does not need to be motivated by a separate constraint; as long as *Share is ranked above Max, the CL candidate will be more harmonic than the candidate that has a shared mora. And regardless of where this constraint is ranked, the consonant will not be deleted until after the mora-sharing step—as we have seen, gradualness makes it impossible to delete the consonant altogether in either of the previous two steps.

(55) *Third iteration: CL*

$\mu\ \mu\ \ \ \mu$ k ɨ H n ɨ	WBP	*l/Coda	Max[Place]	*μ/C	*Share	Dep-L[μ]	Max
$\mu\ \mu\ \ \ \mu$ a. k ɨ H n ɨ					*!		
$\mu\ \mu\ \ \ \mu$ b. ☞ k ɨ n ɨ							*

In this pass through the constraint ranking, shown in the tableau in (55), the CL candidate (b) wins because it violates only Max, which is ranked very low. The faithful candidate (a), which contains a shared mora, is eliminated because *Share dominates Max. After this, the derivation will converge, as no further change to the CL candidate better satisfies the constraint ranking.

This analysis also makes the correct predictions for Komi Ižma forms that contain /l/ in onset position. Consider the underlying form /kɨl+i/ 'hear-1sg.past'. With that input, the derivation converges on the first pass, as no possible candidate better satisfies the constraint ranking than the faithful one. In particular, no advantage is gained from deleting the /l/'s place feature, as shown in (56):

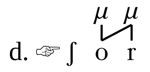
(56) *First iteration: Convergence*

$\mu\ \ \ \mu$ k ɨ l i	WBP	*l/Coda	Max[Place]	*μ/C	*Share	Dep-L[μ]	Max
$\mu\ \ \ \mu$ a. ☞ k ɨ l i							
$\mu\ \ \ \mu$ b. k ɨ H i			*!				

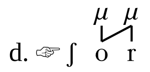
In the tableau in (56), the faithful candidate is the winner in the first step of the derivation because it violates none of the relevant constraints, either markedness or faithfulness. The placeless consonant in candidate (b), on the other hand, fatally violates Max[Place]. Thus, the analysis correctly predicts neither deletion nor lengthening when an /l/ appears in onset position.

Finally, the gradual deletion approach correctly predicts the absence of CL when a consonant other than /l/ appears in coda position. To illustrate this, consider the word /ʃor/, meaning 'house'. This word has an /r/ in coda position, and there is neither deletion nor lengthening in the derivation. Here, too, Richness of the Base requires consideration of inputs with moraic consonants as well as inputs with non-moraic consonants. In either case, the first pass through the constraint ranking produces a form that retains the coda /r/ but has the coda's mora shared between the coda consonant and the preceding vowel:

(57) *First iteration: Mora sharing*

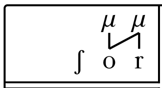
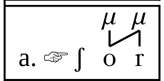
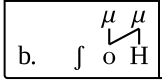
ʃ $\overset{\mu}{\text{o}}$ r	WBP	*l/CODA	MAX[Place]	*μ/C	*SHARE	DEP-L[μ]	MAX
a. ʃ $\overset{\mu}{\text{o}}$ r	*!						
b. ʃ $\overset{\mu}{\text{o}}$ $\overset{\mu}{\text{r}}$				*!			
c. ʃ $\overset{\mu}{\text{o}}$ $\overset{\mu}{\text{H}}$			*!	*			
d. ☞ 					*	*	

(58) *First iteration: Mora sharing*

ʃ $\overset{\mu}{\text{o}}$ $\overset{\mu}{\text{r}}$	WBP	*l/CODA	MAX[Place]	*μ/C	*SHARE	DEP-L[μ]	MAX
a. ʃ $\overset{\mu}{\text{o}}$ $\overset{\mu}{\text{r}}$				*!			
b. ʃ $\overset{\mu}{\text{o}}$ r	*!						
c. ʃ $\overset{\mu}{\text{o}}$ $\overset{\mu}{\text{H}}$			*!	*			
d. ☞ 					*	*	

The same set of faithfulness violations is incurred by the candidates in both (57) and (58), precisely because inserting a mora associated with the coda consonant does not incur any violations. *l/CODA has no effect because there is no coda /l/; therefore, there is no motivation for deletion of the coda consonant. In both cases, the form with a non-moraic coda is ruled out by undominated WBP. The form with a moraic /r/ fatally violates *μ/C because its mora is associated only with the consonant. Candidate (c), which contains a placeless consonant, also violates *μ/C and is ruled out by MAX[place]. Candidate (d), then, emerges as the winner because it violates only the relatively low-ranking constraints *SHARE and DEP-L[μ]. The form with the shared mora becomes the input to the next iteration:

(59) *Second iteration: Convergence*

	WBP	*l/CODA	MAX[Place]	*μ/C	*SHARE	DEP-L[μ]	MAX
a. ☞ 					*		
b. 			*!		*		

As the tableau in (59) shows, the derivation converges on a form containing a shared mora. The faithful candidate violates only *SHARE. The candidate with a placeless coda consonant is harmonically bounded because it also violates the higher-ranked MAX[Place], so there is no change to the mora-sharing form that will better satisfy the constraint hierarchy. Notice that CL is not an option at this point; deleting the coda /r/ would violate both MAX[Place] and MAX. And because candidate (b), with its placeless consonant, is harmonically bounded, this deletion will never get off the ground. The gradual deletion analysis, because it encourages mora-sharing, predicts closed-syllable lengthening in languages that have CL; as we will see later, this prediction is borne out in Komi Ižma (Igushev, 1972).

It seems, then, that we have derived CL in HS, with the analysis crucially relying on gradual deletion to ensure that coda consonants are not deleted before they can be associated with moras. Unfortunately, there is a large class of cases of canonical CL that gradual deletion cannot account for. I turn to that class of examples now.

5.3 Problems with the gradual deletion approach

5.3.1 Empirical inadequacy

Laryngeal consonants, among them /h/ and /ʔ/, are very common triggers of CL. Deletion of /h/ causes lengthening in colloquial Turkish (Sezer 1985; see Section 2) and in various dialects of Farsi (Kavitskaya 2002; Darzi 1991; see Section 2). Loss of /ʔ/ trigers lengthening in colloquial Tehrani Farsi (Darzi 1991; see Section 2) and Ket (Kavitskaya, 2002), as well as in Bella Coola, Choctaw, Klamath, Leti, Mohawk, and Wanka Quechua (mentioned in Kavitskaya 2002). Representative examples from Bella Coola and Choctaw are shown in (60) and (61) below.

(60) /ɬuʔk/ → [ɬukˀ] ~ [ɬuːk] ‘repulsive’ (Bagemihl 1991, (67))

(61) /kowiʔ-pa-t/ → [kowiːpat] ‘this mountain lion (subject)’ (Ulrich 1993, (14b))

A further, particularly well-known historical example of synchronic CL triggered by loss of laryngeal consonants is found in Indo-European, as illustrated in (62). Proto-Indo-European had several laryngeal consonants that were lost as the language developed, triggering compensatory lengthening and leading to contrasts in vowel length.

(62) Proto-Indo-European $*\text{wéilh}_1\text{s}$ ‘you would want’ → Proto-Germanic wilīz ‘you want’(Ringe 2008, p. 78)

This is a problematic body of facts for the gradual deletion approach to CL because laryngeal consonants are generally assumed to be placeless (Iverson, 1989; McCarthy, 1988). Deletion of laryngeal consonants, therefore, can take place in a single derivational step even if gradual deletion is assumed. And if deletion can occur in one step, we run into the same problem we saw in the non-gradual approach: It will always be better to delete a non-moraic coda consonant before it can be associated with a mora than it is to leave the consonant in place, assign it a mora, share that mora with the preceding vowel, and then delete the consonant.

To illustrate this problem, consider an example of Turkish *h*-deletion. Recall that, in colloquial Turkish, /h/ is deleted from coda position when it precedes a nasal stop or a continuant. This deletion causes lengthening of the preceding vowel, and must be motivated by a phonotactic constraint of the following form:[12]

(63) hCond
Assign one violation for every instance of /h/ in the output that is either:
a. Preceded by a vowel and followed by a continuant or a nasal stop, or
b. preceded by a vowel or a voiceless consonant and followed by a vowel.

Because hCond is the constraint that motivates deletion, it is the counterpart of *l/Coda in the Komi Ižma example from Section 5.2. To see the effect of this constraint, consider the derivation of /tahsil/ ‘education’. Consider first an input containing a non-moraic /h/. (Segments that would surface as /h/ are represented as H in the tableaux that follow to emphasize the fact that the consonant is not inherently associated with a place feature.) The first pass through the constraint ranking, shown in (64), shows that deletion is preferred to mora-sharing:

(64) *First iteration: Deletion*

t $\overset{\mu}{\text{a}}$ H s $\overset{\mu}{\text{i}}$ l	WBP	hCond	Max[Place]	*μ/C	*Share	Dep-L[μ]	Max
a. t $\overset{\mu}{\text{a}}$ H s $\overset{\mu}{\text{i}}$ l	*!	*					
b. t $\overset{\mu}{\text{a}}$ $\overset{\mu}{\text{H}}$ s $\overset{\mu}{\text{i}}$ $\overset{\mu}{\text{l}}$		*!		*			
c. ☞ t $\overset{\mu}{\text{a}}$ s $\overset{\mu}{\text{i}}$ $\overset{\mu}{\text{l}}$							*
d. ☹ t $\overset{\mu\ \mu}{\text{a}}$ $\overset{\mu}{\text{H}}$ s $\overset{\mu}{\text{i}}$ $\overset{\mu}{\text{l}}$		*!			*	*	

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[12] Admittedly, this is not a particularly coherent phonotactic constraint; however, I see no coherent way of characterizing the environments from which /h/ is deleted.

The faithful candidate, which contains a non-moraic coda consonant, is ruled out by the highly-ranked WBP. Candidate (b) avoids that violation with a moraic H in coda position, but it incurs a fatal violation of hCond. The desired winner, candidate (d), is ruled out thanks to the violation of hCond that it too incurs. This means that the winning candidate is (c), which violates only Max. We have seen that an intermediate stage of mora-sharing is necessary for the successful analysis of CL in HS, but with this ranking, we cannot get to the mora-sharing stage unless the consonant in coda position is underlyingly specified for place. Notice, too, that the problem persists for inputs that have a mora associated with the /h/. Again, because the positional mora can be inserted without penalty, the candidate set for the non-moraic input is the same as the constraint set for the moraically specified input.

Furthermore, it is not the case that this problem can be solved by ranking Max above hCond. The Max ≫ hCond ranking will allow the mora-sharing candidate (d) to be the output of the first step in the derivation, but we will encounter a different problem on the second pass. The first two steps of this derivation are shown in (65) and (66), respectively.

(65) *First iteration: Mora sharing*

t $\overset{\mu}{\text{a}}$ H s $\overset{\mu}{\text{i}}$ l	WBP	Max	hCond	Max[Place]	*μ/C	*Share	Dep-L[μ]
a. t $\overset{\mu}{\text{a}}$ H s $\overset{\mu}{\text{i}}$ l	*!		*				
b. t $\overset{\mu}{\text{a}}$ $\overset{\mu}{\text{H}}$ s $\overset{\mu}{\text{i}}$ $\overset{\mu}{\text{l}}$			*		*!		
c. t $\overset{\mu}{\text{a}}$ s $\overset{\mu}{\text{i}}$ $\overset{\mu}{\text{l}}$		*!					
d. ☞ t $\overset{\mu\ \mu}{\text{a H}}$ s $\overset{\mu}{\text{i}}$ $\overset{\mu}{\text{l}}$			*			*	*

(66) *Second iteration: Convergence*

t $\overset{\mu}{\text{a}}$ h s $\overset{\mu}{\text{i}}$ l	WBP	Max	hCond	Max[Place]	*μ/C	*Share	Dep-L[μ]
a. ☞ t $\overset{\mu\ \mu}{\text{a H}}$ s $\overset{\mu}{\text{i}}$ $\overset{\mu}{\text{l}}$			*			*	
b. ☹ t $\overset{\mu\ \mu}{\text{a}}$ s $\overset{\mu}{\text{i}}$ $\overset{\mu}{\text{l}}$		*!					

With the revised constraint ranking, candidate (65d), which has a shared mora, does indeed serve as the input to the second step. At that point, though, the derivation converges on the candidate with the shared mora. The tableau in (66) shows that, if Max is ranked above hCond, deletion will never be available as a repair strategy for violations of hCond and lengthening will never occur. This is another instance of the familiar ranking paradox that arises when consonants can be deleted in one step: In order for the consonant to be assigned a mora, Max must dominate the constraint that motivates deletion of the consonant. But if that consonant is to be deleted at any point in the derivation, the constraint that motivates its deletion must be ranked above Max. Because the gradual deletion approach crucially relies on deleting the place feature first, leaving the underspecified consonant syllabified long enough to be associated with a mora, it cannot account for cases in which the consonant in question already lacks place features. So while gradual deletion of consonants seems like a promising analytical tool in that it helps account for many canonical instances of CL, it is clear that something else must be said to account for the full range of triggers for lengthening.

5.3.2 Theoretical concerns

In addition to the lack of empirical coverage, the gradual deletion approach raises a number of theoretical concerns. Foremost among these questions is the nature of the placeless consonant in the intermediate representations. What is the motivation for positing this particular intermediate form? The existence of /H/ is based on the assumption that Max[Place] and Dep[Place], rather than Ident[Place], are the appropriate constraints for restricting changes to place features. In this framework, though, other properties that are usually represented as features are tacitly assumed to be governed by Ident constraints. What is the motivation for treating [+coronal] as an entity autosegmentally linked to a consonant while [+voice] is treated as an attribute of a segment? Segments can assimilate to adjacent segments in either place or in some other feature like voicing or nasality, so it is not the case that the former behaves like an entity while the latter behaves like an attribute, at least in that case.

Furthermore, it is not clear what the other properties of this placeless consonant would be. If we take seriously the idea that each intermediate step in the derivation must be a possible output in some language, we are committed to the idea that the /H/ in the derivations above is pronounceable. In some languages—Caribbean Spanish, for example—there is evidence of debuccalization to /h/ (Terrell, 1979). At the same time, though, we have evidence from CL triggered by the loss of laryngeal consonants that this /H/ cannot be formally equivalent to /h/; /H/ cannot trigger CL when it is deleted, but /h/ demonstrably does. This difference cannot be resolved by assuming that /h/ is inherently associated with a place feature because, if that were the case, we would still not have an explanation of how /H/ should be pronounced. In other words, the only way to account for CL with gradual deletion would be to assume that /H/ is pronounced exactly the same way as /h/ but that /h/ has its own place feature while /H/ does not.

McCarthy (2008a) admits the possibility that languages choose whether or not their laryngeal consonants are associated with a [pharyngeal] place feature. Tigre, it is claimed, allows /ʔ/ in coda position only when it derives from debuccalization of /$k^{ʔ}$/; underlying /ʔ/ and /h/ are barred from surfacing in coda position. However, this evidence is not particularly convincing. First, the data cited in that paper are from Rose (1996), which clearly shows that /ʔ/ is allowed in coda position, at least word-finally. Secondly, Tigre uses epenthesis as a repair strategy for removing consonants (including, but not limited to, laryngeals) from coda position, and it seems plausible that such epenthesis would occur before debuccalization. Finally, it is still redundant to posit two consonants that are pronounced in exactly the same way but have two distinct featural representations. If the placeless consonants are indeed pronounced as /h/ and /ʔ/, there is little empirical reason for distinguishing the two.

Even this set of assumptions would not be enough, though. If /H/ is a pronounceable consonant that has had its place features deleted, it should retain the rest of the features of the corresponding underlying consonant. In a way, this idea is sensible—if the original consonant is sonorant, for example, the /H/ derived from it should also be sonorant. Such a system could intuitively capture two possible ways of deleting coda consonants. In the case of a sonorant coda like /l/, the consonant could be heard and reinterpreted as part of the nucleus, perhaps triggering CL (Kavitskaya, 2002). Other, less sonorant consonants might weaken to the point where they can hardly be heard at all. This latter type of deletion might indeed plausibly include an intermediate stage of something like /h/. But this algorithm will not always produce a valid speech sound. It is not clear how a placeless consonant derived from a nasal could be pronounced given that nasal consonants must by definition have a place of articulation no more back than velar. Similarly, /l/ ought to have a [lateral] feature that is retained even when the [coronal] place feature is deleted. Again, it is not clear how a placeless lateral would be pronounced. It is also difficult to imagine what a HS-compliant theory of features would look like. Changing other features contingent on deletion of the consonant seems like a plausible strategy until we consider the fact that, under other circumstances, such changes should incur violations of Ident constraints. The only solution is to change the basic definition of gradualness: As many Ident[F] constraints as necessary can be violated only when Max[Place] is violated; otherwise, only one Ident[F] violation is allowed. In other words, the only way to maintain the claim that intermediate stages of the derivation are all pronounceable is to change one of the fundamental properties of HS and abandon the tenet of gradualness.

The gradual deletion approach was designed to account for phenomena that make reference to coda consonants: cluster simplification, in which only the coda consonant is deleted; nasal assimilation, in which only the coda assimilates; and CL, in which only loss of the coda triggers lengthening. The only purpose the intermediate placeless consonant serves, then, is to ensure that the consonant retains the relevant properties long enough to be syllabified into a coda and thus be differentiated from an onset. It certainly makes sense, at least in some cases, that coda consonants go through an intermediate, moraically specified stage during the derivation of CL, but there is less evidence that gradual deletion is necessary for the deletion of onsets. If gradual deletion accounts for the directionality of cluster simplification and nasal assimilation simply because CodaCond is highly ranked, the factorial typology would lead us to expect more languages in which the processes occur in the opposite direction. And, at the same time, gradual deletion is designed to account for directionality but is not adequate for the analysis of a directional phenomenon like CL. It is clear that we need some other mechanism if we want to derive CL

What gradual deletion does get us (at least in the case of non-laryngeal consonants) is syllabification of an intermediate representation before segmental deletion can occur. Several tradeoffs are made to get this result, though. The analysis requires an abstract intermediate representation that is probably not pronounceable. Further, no consonant that has a place feature associated with it can be deleted until that place feature deleted (or shared with an adjacent segment). Any time MAX is violated, MAX[Place] (or NOLINK[Place])[13] must have been violated in some previous derivational step. This property of the constraint set is effectively equivalent to building an OT-CC-style PREC constraint into HS. PREC constraints are much-maligned for stipulating the order of violations in OT-CC, and using another mechanism for stipulating the order of constraints in HS is equally undesirable. Even in a gradual framework like HS, the derivation should not be arbitrarily constrained by what has happened in previous steps. Each step refers only to the output of the previous step, and each pass should be blind to the internal workings of the previous passes. The order of violations incurred should be determined only by the constraint ranking. If gradual deletion cannot account for all of the empirical phenomena and has additional, theoretically undesirable consequences, it should be abandoned in favor of some other approach to the analysis of CL.

6 Compensatory lengthening with a fully faithful candidate

We have seen that the successful analysis of CL in HS depends crucially on some way of ensuring that the coda consonant that will eventually be deleted is present in the intermediate representation(s) long enough to be associated with a mora. In Section 5, I showed that deleting consonants in more than one step is a promising but ultimately insufficient mechanism for accomplishing just that. In this section, I will argue that using a syllabified, moraically specified form as the input to the first pass through the constraint ranking leads to a simpler analysis of CL that has broader empirical coverage.

6.1 Determining the FFC

If the derivation is to begin with a FFC, we must first know what that FFC is. This concept is defined in OT-CC as the most harmonic form that violates no basic faithfulness constraints, and that definition is equally applicable here. The FFC will be a form with the same segmental makeup as the input, as MAX, DEP, and IDENT are all basic faithfulness constraints. The only allowable changes are those that are not governed by faithfulness constraints—syllabification and moraic structure.

Syllabification uncontroversially comes for free: In all stages of the derivation, each candidate is syllabified, and the optimal syllabification may change depending on the segmental changes that occur over the course of the derivation. This property of syllabification is also consistent with traditional derivational analyses in which syllabification is an "everywhere rule" (meaning that it applies at every point in the derivation). And we saw in Section 4.3 that insertion and deletion of positional moras—those moras that do not change segment length—must also come for free. Again, this ability to build moraic structure without penalty makes sense when we consider the fact that syllabic structure is also built without penalty. If a language assigns moras to all of its coda consonants and if the status of a particular consonant as a coda can change over the course of the derivation, it must be possible to associate positional moras with those coda consonants when the form is resyllabified. Otherwise, it would not be possible to consider a candidate with a well-formed moraic coda in a single step.

Furthermore, the gradual deletion analysis has shown us that syllabification must be present before segments can be deleted in CL. In other words, we need to know which consonants are codas before we can derive CL. Because syllabic and moraic structure is not governed by faithfulness constraints and therefore cannot constitute its own derivational step, there is nothing to prevent prosodic structure from being built before the derivation proper begins. If we wait until GEN produces the first set of candidates to add syllable structure, we encounter a problem: The faithful candidate in the first step is a syllabified form of the input, but the candidates to which it is compared also incur a

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[13] NOLINK[Place] penalizes linking of place features and segments that are not linked in the input.

(i) NOLINK[Place]
Let *input segmental tier* = $i_1 i_2 i_3 \ldots i_m$ and *output segmental tier* = $o_1 o_2 o_3 \ldots o_n$.
Let *input place tier* = $p_1 p_2 p_3 \ldots p_q$ and *output segmental tier* = $P_1 P_2 P_3 \ldots P_r$.
Assign one violation mark for every pair (P_y, o_z) where
P_y is associated with o_z,
p_w is in correspondence with P_y,
i_x is in correspondence with o_z, and
p_w is not associated with i_x. (McCarthy 2008a (5))

faithfulness violation. In a derivation where one of the non-faithful candidates is the winner of the first stage, that winner is never evaluated with respect to a syllabified version of the input and therefore cannot make reference to any of the prosodic properties of the input. This is a problem for CL, as we have seen. If we do not begin the derivation with a syllabified form, we cannot be guaranteed to begin the derivation with moras associated with the appropriate consonants. The first iteration, then, compares a syllabified and moraically specified form of the input with forms that have undergone some segmental change and then been syllabified. The candidates that have undergone segmental changes do not have access to the correct moraic structure for the underlying representation, only the moraic structure that happens to be present in the input. Beginning the derivation with a FFC eliminates this problem; all candidates are evaluated with respect to an initial input that has a chance of being a well-formed surface word: a form that is syllabified and moraically specified according to the language's constraint hierarchy.

The FFC is determined relative to the same constraint ranking that governs the rest of the derivation, the difference being that only candidates that do not violate any faithfulness constraints are considered. Because no faithfulness violations are incurred by any of the candidates, the entire prosodic structure can be built at once. There is no need for gradualness in this process because none of the changes could constitute their own derivational step in a gradual derivation. In other words, there is no motivation for inserting one positional mora at a time because inserting three moras associated with three coda consonants involves the same number of faithfulness violations (zero) as inserting one mora associated with a single coda consonant. The relevant constraints in determining the FFC are WBP and those constraints that determine which consonants are syllabified as onsets and which are syllabified as codas. Building this prosodic structure before the derivation begins ensures that the input to the first step has the best possible chance of being a well-formed surface word, and it ensures that the candidates in that first step are compared to a faithful form that is well-formed.

6.2 The derivation

As mentioned above, Richness of the Base forces us to consider both cases where the consonant that will be deleted is underlyingly associated with a mora and cases where the consonant that will be deleted is not associated with a mora in the underlying representation. Given a CVC input, the FFC in a derivation of CL must have a moraic coda consonant:

(67) *Determining the FFC from the input*

$$/\text{C}\ \overset{\mu}{\text{V}}\ \text{C}/ \quad \rightarrow \quad [\text{C}\ \overset{\mu}{\text{V}}\ \overset{\mu}{\text{C}}]$$

This step must occur without penalty because a ranking paradox arises if insertion of the mora associated with the coda consonant constitutes its own derivational step. For an input with a non-moraic coda, Max must be ranked above NoCoda to prevent the coda from being deleted before it can be associated with a mora:

(68) Max ≫ NoCoda *to insert a mora*

$\text{C}\ \overset{\mu}{\text{V}}\ \text{C}$	WBP	Max	NoCoda	P-Dep[μ]
a. ☞ $\text{C}\ \overset{\mu}{\text{V}}\ \overset{\mu}{\text{C}}$			*	
b. $\text{C}\ \overset{\mu}{\text{V}}$		*!		

But if the coda consonant is to delete later in the derivation, NoCoda must dominate Max. Making $[\text{CV}^{\mu}\text{C}^{\mu}]$ the FFC resolves this ranking paradox because a mora is inserted before the derivation begins. The first pass through the constraint ranking, then, has a moraically specified input, and there is no need for the coda to be preserved at the expense of violating NoCoda.

Making $[\text{CV}^{\mu}\text{C}^{\mu}]$ the FFC means that some version of Dep[μ] is not a basic faithfulness constraint. This constraint cannot be Dep[μ] itself; inserting a mora to lengthen an underlying short vowel or geminate an underlying singleton consonant is certainly a faithfulness violation. P-Dep[μ], which penalizes only the insertion of moras that change the length of a segment, is a better option. What is important for our purposes is that inserting a mora does not incur a violation of P-DEP[μ] exactly when that mora is required to fulfill constraints on syllable wellformedness. And once a FFC with a moraic coda has been established, the derivation can proceed.

Notice that arriving at a particular FFC is a language-specific process. Because the FFC is defined as the most harmonic candidate that violates no basic faithfulness constraints, other aspects of the language's constraint hierarchy come into play in determining the form's syllabification. Constraints that determine whether a given segment will be syllabified as an onset or a coda and WBP, for example, can be violated or satisfied depending on their relative ranking.

Notice, too, that it would not suffice to rank all of the constraints on syllable wellformedness above the constraints that govern CL. At first glance, doing so seems like a plausible strategy given that the constraint ranking in HS effectively serves to prioritize the order in which problems are repaired—violations of high-ranking markedness constraints are removed first, then the derivation moves on to alleviating lower-ranked violations. But the motivation for beginning the derivation with a FFC is that there is a ranking paradox if moraic structure is not fixed before the derivation begins. This ranking paradox will persist regardless of *when* moraic structure is derived by constraint—it will never be possible to insert a mora without deleting the coda consonant at one step in the derivation and still delete the consonant later. It must be the case that arriving at the FFC is a separate (but still constraint-based) process that occurs before the derivation proper begins.

6.2.1 CL triggered by loss of /l/: Komi Ižma

To illustrate an HS derivation of CL, I will use the Komi Ižma data from (6). Recall that, in this language, /l/ is deleted and triggers CL of the preceding vowel when the /l/ is word-final or stem-final and followed by a consonant.

The constraints required for the derivation are summarized in (69):

(69) *Relevant constraints*

a. WBP
Assign a violation for each coda consonant that is not dominated by a mora.

b. *FLOAT
Assign a violation for each mora in the output that is not associated with a segment.

c. MAX[μ]
Assign a violation for each mora in the input that is not present in the output.

d. *l/CODA
Assign a violation for every word- or stem-final /l/ that is followed by a consonant in the output.

e. MAX
Assign a violation for each segment in the input that is not present in the output.

f. *μ/C
Assign a violation for each mora that does not dominate a vowel.

g. DEP-L[μ]
Assign a violation for each segment that is not associated with a mora μ_i in the input but is associated with μ_i in the output.

h. *SHARE
Assign a violation for each mora that dominates more than one segment in the output.

Some of these constraints require further elaboration. WBP assigns violations to coda consonants in the output that are not associated with a mora. The associated mora may exclusively dominate the coda consonant or it may be shared between the consonant and the preceding vowel. This constraint as formalized here does not penalize candidates in which onset consonants are associated with moras; for simplicity, such candidates will not be considered in the analysis that follows.

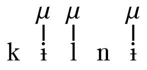
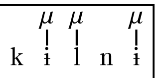
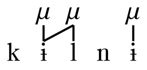
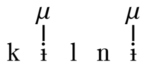
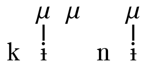
*l/CODA is a language-specific cover constraint that penalizes word- or stem-final /l/ when followed by a consonant. While it may be possible to derive this pattern from other constraints that are active in this dialect, a general cover constraint will simplify the analysis significantly. The important point is that this is the constraint that motivates deletion of the moraic coda consonant.

*μ/C, following Broselow et al. 1997, penalizes only moras that *exclusively* dominate a consonant—moras that are shared between a consonant and an adjacent vowel do not incur violations of this constraint because the head of that mora is vocalic. This constraint is motivated because vowels are more sonorant than consonants, so they are

preferred hosts for moras. The less sonorant a segment is, the less able it is to host a unit of length or weight. All languages have moraic vowels; whether consonants are associated with moras and what sonority threshold is required for that association is a language-particular matter. *Share, on the other hand, assigns violations to moras that are shared between segments. This structure is marked because of its complexity; *Share is the markedness constraint that is violated when a mora which is already associated with a segment is linked with another segment.

The first iteration Recall that the derivation begins with a FFC—a fully moraically specified form. Because Komi Ižma has undominated WBP, the FFC for the input /kɨlnɨ/ is [kɨ$^{\mu}$l$^{\mu}$nɨ$^{\mu}$]. This form serves as the input to the first pass through the constraint set, where the most harmonic candidate is one in which the mora originally associated with the coda consonant is shared between that consonant and the preceding vowel:

(70) *First iteration: Mora sharing*

	WBP	*Float	Max[μ]	*l/Coda	Max	*μ/C	Dep-L[μ]	*Share
a. 				*		*!		
b. ☞ 				*			*	*
c. 	*!		*	*				
d. 		*!			*			

The faithful candidate (a) is ruled out by *μ/C; sharing a mora between the coda and the preceding nucleus is a better strategy for satisfying WBP than allowing a the coda to be associated with its own unique mora. Candidate (c), which contains a non-moraic coda, is ruled out by undominated WBP. The winner is candidate (b), which contains a shared mora. This structure is sensible because there is phonetic evidence from vowel duration that shared moras are utilized productively in languages like Malayalam and Levantine Arabic (Broselow et al., 1997), and there is phonetic evidence that this mora-sharing structure is utilized in Komi Ižma as well.

Excursus: Floating moras? In the tableau in (70), candidate (d) would be the next step in a rule-based autosegmental analysis. There is, however, reason for wanting to rule it out in a HS derivation. It is unclear what constraint would be used to ensure that the newly floating mora is associated with the adjacent vowel in the next pass through the constraint ranking. In other words, what would prevent a candidate like [kɨnɨː], with non-local lengthening, from emerging as the winning candidate later? It would not be possible to include a constraint requiring moras to remain within the syllable because, as we will see, CL triggered by glide formation sometimes involves concomitant resyllabification.

There are two logically possible constraint-based ways of ensuring that (70d) is not the winning candidate. Here, *Float is high-ranking. Ranking Max above CodaCond is another option, but it leads to a familiar ranking paradox; if the coda remaining in the winning candidate is to delete at a later point in the derivation CodaCond must be ranked above Max. In short, eliminating a candidate with a floating mora using constraints other than *Float replicates the problem caused if Dep[μ] is a basic faithfulness constraint.

We might be tempted to rule (70d) out on the theory-internal grounds that it is not harmonically improving. HS predicts that, for any candidate generated by the framework's restricted version of Gen, some language will converge on that output. In this case, we predict the existence of a language that deletes moraic coda consonants but leaves a floating mora in the surface representation. Such a language might be troublesome in that it allows moras that have no corresponding effect on segment length or on syllable weight, but in practical terms it would be impossible to distinguish that language from one that deletes both the coda consonant and the associated mora.[14] Perhaps, for example, a representation containing a floating mora is phonologically valid, but the phonetics simply ignores the unassociated mora. While claiming that the floating mora has no phonetic effect is a possible—and perhaps even

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[14] Thanks to Ryan Bennett for valuable discussion of this point.

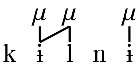
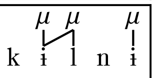
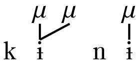
plausible—solution, it is at best theoretically uncomfortable to claim that floating moras surface in some language. The combination of the inability to guarantee that the floating mora is reassociated with the appropriate segment and the unpronounceablity of the form itself mean that the form with the floating mora should not be a valit intermediate representation.

For that reason, I will follow Shaw (2007) in assuming that forms containing floating moras are not created by GEN and that such forms are not possible surface forms in any language. Notice that this claim has consequences for languages in which consonants are deleted without triggering lengthening in an adjacent segment. To illustrate this point, consider a language that differs minimally from Komi Ižma: coda consonants are uniformly moraic and /l/ is deleted when it would surface in coda position, but deletion does not trigger lengthening. Deleting both the segment and the mora at the same time violates both MAX and MAX[μ] and is ruled out by gradualness. The mora could be deleted without violating WBP, while the consonant could not be deleted without leaving a floating mora (Mora sharing is only motivated where there is lengthening of the adjacent segment.). This means that the only possible analysis is one in which the /l/ that is deleted is never assigned a mora at all. In other words, WBP must be dominated by a language-particular constraint that prevents /l/ from being associated with a mora. The FFC, then, would contain a non-moraic coda consonant, which is later deleted in a single step.

To summarize the discussion, I will from this point forward assume that forms that contain floating moras cannot be generated. This assumption renders *FLOAT unnecessary; that constraint will not be included in the tableaux that follow.

The second iteration Recall that the winning candidate and input to the next stage of the derivation is (70b), the candidate with a shared mora. The crucial ranking is *μ/C ≫ DEP-L[μ], *SHARE. The next pass through the constraint set produces the CL candiate:

(71) *Second iteration: CL*

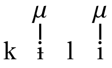
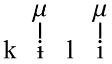
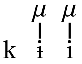
	WBP	MAX[μ]	*l/CODA	MAX	*μ/C	DEP-L[μ]	*SHARE
a. 			*!				*
b. ☞ 				*			

Here, the crucial ranking is *lCODA ≫ MAX. The faithful candidate (a) loses because the constraint that penalizes stem-final /l/ is ranked above the constraint that penalizes deletion. Notice, too, that the winning candidate does not incur a violation of MAX-L[μ]. While that constraint penalizes segments that are associated with a mora in the input but are not associated with a mora in the output, it assigns no violations when the segment in question is present in the input but not in the output. Deletion of a segment linked to a mora violates only one faithfulness constraint (MAX), and is therefore licit under the assumptions of HS. At this point, the derivation converges—no further change to (71b) will be harmonically improving (better satisfy the constraint ranking).

We have derived CL in HS. Notice, though, that the derivation crucially depends on two assumptions. First, violations of P-DEP[μ] are not incurred if the inserted mora satisfies constraints on syllable wellformedness. And second, DEP-L[μ] must be defined so that it is not violated when a new mora is inserted.

The analysis also correctly derives cases where no CL occurs. When /l/ is not in coda position, there is no motivation for it to delete, and the derivation converges on the FFC. The FFC for an input /kɨli/ is [kɨ$^{\mu}$li$^{\mu}$]. No mora is associated with the [l] in this case because that consonant is syllabified as an onset:

(72) *First iteration: No CL*

	WBP	MAX[μ]	*lCODA	MAX	*μ/C	DEP-L[μ]	*SHARE
a. ☞ 							
b. 				*!			

The FFC analysis, then, correctly predicts CL in Komi Ižma in cases where /l/ is deleted from coda position and correctly predicts no deletion nor lengthening where /l/ surfaces as an onset. The derivation begins with a syllabified and moraically specified form and relies on an intermediate stage of mora-sharing. As we will see, this analysis also makes the right predictions about other, potentially more complex cases of CL.

6.2.2 CL triggered by loss of /h/: Turkish

The FFC analysis of CL extends trivially to the problematic cases for the gradual deletion analysis—those in which CL is triggered by the loss of a laryngeal consonant—because the analysis does not rely at all on the identity of the CL trigger. The only difference is the language-particular constraint that motivates deletion. For Turkish, this constraint is hCond. The FFC for the input /tahsil/ is assumed to be /ta$^{\mu}$h$^{\mu}$.si$^{\mu}$l$^{\mu}$/, with moraic coda consonants, regardless of whether those moras are present in the input itself.[15]

(73) *First iteration: Mora sharing*

μ μ μ μ t a h s i l	WBP	Max[μ]	hCond	Max	*μ/C	Dep-L[μ]	*Share
a. μ μ μ μ t a h s i l			*		*!		
b. ☞ μ μ μ μ t a h s i l			*			*	*
c. μ μ t a h s i l	*!	*	*				

As in the analysis of the Komi Ižma forms, the faithful candidate (a) is ruled out by *μ/C because mora-sharing is preferred over having a coda consonant associated with its own mora. Candidate (c), which contains a non-moraic coda, is ruled out by undominated WBP. The mora-sharing candidate (b) is the winner and the input to the next step in the derivation. In that step, shown in (74) below, the CL candidate emerges as the winner because the constraint that favors deletion of /h/, hCond, is ranked above Max.

(74) *Second iteration: CL*

μ μ μ μ t a h s i l	WBP	Max[μ]	hCond	Max	*μ/C	Dep-L[μ]	*Share
a. μ μ μ μ t a h s i l			*!				*
b. ☞ μ μ μ μ t a s i l				*			

After this stage, the derivation will converge because there is no change to the CL form that better satisfies the constraint hierarchy. The FFC analysis correctly derives CL in a way that the gradual deletion analysis cannot. Furthermore, the FFC analysis also makes the correct predictions about forms that have (a) no deletion, or (b) deletion but not lengthening. Deriving [süpe] from /šüphe/ (19b) begins with the FFC /šü$^{\mu}$p$^{\mu}$he$^{\mu}$/.

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[15] For the sake of illustration, the violations incurred by the second syllable are not included in the tableaux. The same mora-sharing process must occur in the second syllable, but I make no claims about the relative order of changes across syllables.

(75) *First iteration: Deletion*

μ μ μ š ü p h e	WBP	MAX[μ]	hCOND	MAX	*μ/C	DEP-L[μ]	*SHARE
μ μ μ a. š ü p h e			*!		*		
μ μ μ b. š ü p h e			*!			*	*
μ μ c. ☞ š ü p e				*			

Because hCOND is ranked above MAX and because the /h/ is not associated with a mora in the FFC, the the consonant is deleted immediately. Both the faithful candidate (a) and the mora-sharing candidate (b) are eliminated by hCOND, which penalizes the /phe/ sequence. That leaves candidate (c), from which the /h/ has been deleted, as the winner. The derivation will converge after this, as there is no further change that will better satisfy the constraint hierarchy.

6.3 Less canonical CL

6.3.1 CL triggered by non-adjacent deletion: Tehrani Farsi

One apparent exception to the generalization that the deleted segment is immediately adjacent to the lengthened one in canonical CL is found in colloquial Tehrani Farsi. In this dialect, /h/ and /ʔ/ trigger CL when they are deleted from either position in a complex coda:

(76) a. /robʔ/ → [roːb] ‘quarter’ (Darzi 1991, (4a))
b. /roʔb/ → [roːb] ‘terror’ (*ibid.*, (4b))
c. /suʔ/ → [suː] ‘bad’ (*ibid.*)

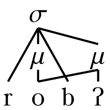
Other consonants are deleted from coda position without triggering CL:

(77) a. /loxt/ → [lox] ‘naked’ (Darzi 1991, (8a))
b. /ʔæz/ → [ʔæ] ‘from’ (*ibid.*, (8b))

The facts in (77) make an account based on either trimoraic syllables or extrametricality of final consonants impossible. If both consonants in a coda cluster were moraic, we would expect the deletion of either member of a coda cluster to trigger CL. The same prediction holds if the final consonant is extrametrical—deletion of the second member of a coda cluster should trigger reanalysis of the remaining consonant as non-moraic, and the mora that was previously associated with it should become linked to the preceding vowel. In either case, deletion of any consonant should trigger the same process. The contrast between (76) and (77) shows that this cannot be the case. We are forced to conclude that /h/ and /ʔ/, but no other consonants, are moraic in this dialect. Kavitskaya 2002 argues that /h/ and /ʔ/ consonants are realized as approximants in Tehrani Farsi, meaning that there is some plausible basis for assigning moras to only these consonants based on sonority.

If we accept this premise, the analysis of the derivation of [roːb] from /roʔb/ is straightforward: The mora associated with the coda consonant is shared with the preceding vowel. The consonant later deletes, leaving a long vowel. The derivation of [roːb] from /robʔ/, on the other hand, is less straightforward. The analysis crucially relies on mora-sharing, but if we apply that here, we get an irredeemably ill-formed syllable:

(78)



Instead, the syllable must look something like (79a) before mora-sharing has occurred. The /b/ must also be associated with the mora if crossed association lines are barred from the representation. If we were to apply a mora-sharing analysis to this form, the intermediate representation would be as in (79b). Deleting the /ʔ/ would then result in the structure in (79c). This is not the correct result, however, as it does not correspond to a CL form but rather to one that has the intermediate-length vowel we see in closed syllables in Komi Ižma. The desired result is as in (79d), where the mora has been de-linked from the /b/.

(79)

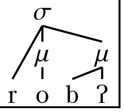
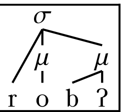
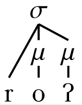
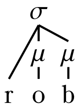
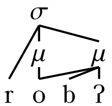
To see if this derivation is possible in the FFC framework, additional assumptions are in order. To begin with, I will follow Kavitskaya (2002) in assuming that /h/ and /ʔ/ are approximants. Because these are the only moraic consonants in the language Tehrani Farsi must contain an undominated constraint parallel to the one that forces vowels to be associated with a mora. This constraint would penalize /h/s and /ʔ/s that are not associated with a mora in the output. Applying this constraint set—where /ʔ/ must be associated with a mora and association lines must not cross—to /robʔ/ results in (79a) as the FFC. The first step in the derivation ought to produce (79b) as its output. Because mora-sharing is driven by *μ/C, it is necessary to recall the definition of that constraint. It penalizes moras that dominate consonants to the exclusion of vowels. This means that mora-sharing is still motivated when a mora dominates two coda consonants. While I know of no phonetic evidence to suggest that (79b) is an attested surface form in any language (and such phonetic evidence would indeed be quite subtle), it is quite logical to assume that languages that have closed-syllable lengthening may also have lengthening in doubly-closed syllables.

Additionally, this language must have another constraint that prevents moras from being associated with, in this case, /b/. This can be stated as a more general constraint against low-sonority consonants being associated with their own moras:

(80) *μ/[obs(truent)]
Assign a violation for each mora that dominates only an obstruent consonant.

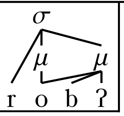
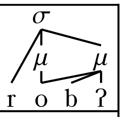
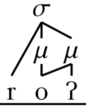
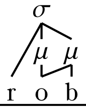
The first step in the derivation is shown in (81):

(81) *First iteration: Mora sharing*

	*μ/[obs]	MAX[μ]	*ʔ/CODA	MAX	*μ/C	DEP-L[μ]	*SHARE
a. 			*		*!		*
b. 			*	*!	*		
c. 	*!			*	*		
d. ☞ 			*			*	*

Notice that no possible candidates that contain ill-formed syllables are included in the candidate set. More specifically, the second mora cannot be delinked from the /b/ because that disassociation would result in the structure in (78). Of the candidates in the tableau in (81), the faithful candidate (a) loses because it violates *μ/C—the second mora is not associated with a vowel. Candidate (b), which deletes the /b/ rather than have it associated with a mora, is eliminated by MAX. And the constraint against moras exclusively dominating obstruent consonants rules out candidate (c), in which the /ʔ/ has been deleted from coda position altogether.[16] The remaining candidate (d) has a mora-sharing structure; like many of the other candidates, it violates *ʔ/CODA, but the other violations it incurs are of the low-ranking constraints DEP-L[μ] and *SHARE. The next step, shown in (82), is to delete the glottal stop from its coda position:

(82) *Second iteration: Deletion*

	*μ/[obs]	MAX[μ]	*ʔ/CODA	MAX	*μ/C	DEP-L[μ]	*SHARE
a. 			*!				*
b. 			*!	*			*
c. ☞ 				*			*

The faithful candidate (a) and the candidate from which /b/ is deleted (b) are eliminated by *ʔ/CODA because the offending glottal stop remains in coda position. That fact leaves candidate (c), from which the glottal stop has been deleted, as the winner. The output of this step is a mora-sharing form. It is possible that this mora-sharing structure is in fact the surface form—the /ʔ/ has been deleted and the preceding vowel has been lengthened. And because only the approximant consonants /h/ and /ʔ/ are associated with moras in the FFC, the analysis does not predict lengthening when other consonants are deleted from the same position. That is, the FFC for the underlying form /loxt/ 'naked' is simply /lo$^{\mu}$xt/. Where there is no mora associated with the deleted consonant, no lengthening occurs. Without phonetic evidence from this dialect of Farsi, though, it is impossible to know whether the desired output is (79c) or (79d). If it is the former, the derivation converges after (82), as there is no change to the input that better satisfies the constraint ranking as shown. If the desired output is a true CL structure with no mora-sharing, however, we have work to do.

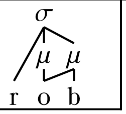
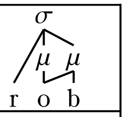
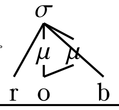
That work requires ranking MAX-L[μ] below *SHARE. This constraint has not been mentioned in previous applications of the analysis because the CL structures in the surface forms are all open syllables, and the mora is only ever shared by the vowel and one immediately adjacent consonant. In this case, though, we want the mora-sharing structure to be destroyed. We need mora-sharing if the derivation is to obey gradualness. On the other hand, the surface representation contains a long vowel that is associated with two moras, not one that occupies one and a half timing units. Delinking the mora from the /b/ does not constitute a Duke-of-York derivation because the /b/ was not linked with its mora during the course of the derivation. The association between the mora and the remaining consonant was instead created out of necessity in the FFC. Removing that link better fits the generalization that consonants other than /h/ and /ʔ/ are not associated with moras in this language.

If we assume that MAX-L[μ] is ranked below *SHARE, the final step in the derivation is as follows:

---

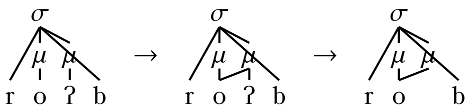
[16] It is possible to construct an alternate analysis that has (81c) as the winning candidate in the first step. Mora sharing would proceed from there, with the /b/ being delinked from its mora in the final stage. This analysis is undesirable for two reasons. First, it dispenses with the connection between deletion of the trigger and lengthening of the vowel in that it predicts lengthening of every vowel that is followed by a moraic coda consonant, even if that consonant is not deleted. Second, it obscures the fact that, in Tehrani Farsi, only /h/ and /ʔ/ are associated with moras when they appear in coda position.

(83) *Third iteration: Lengthening*

	*μ/[obs]	Max[μ]	*ʔ/Coda	Max	*μ/C	Dep-L[μ]	*Share	Max-L[μ]
a. 							*!	
b. ☞ 								*

The faithful candidate loses because it violates *Share. Max-L[μ] is violated by candidate (b), which has a long vowel, but that constraint is ranked below *Share and the violation is not fatal. At this point, the derivation will converge on the CL candidate. This analysis also makes the correct predictions about lengthening in the case where the deleted /ʔ/ is adjacent to the vowel. The derivation will not be shown for the reason that it is exactly parallel to the analysis of Komi Ižma CL, but the sequence of intermediate forms, beginning with the FFC, is given in (84). The FFC analysis, then, can account even for interactions between tautosyllabic but non-adjacent trigers and lengthened vowels. Because this lengthening is triggered by the loss of laryngeal consonants, the gradual deletion analysis would be unable to account for these data. Even in the simplest case, where the /ʔ/ is the only coda consonant in the syllable, the gradual deletion analysis predicts that that consonant would be deleted before it could be associated with a mora. The mora-sharing structure could not be generated, and CL could never get off the ground.

(84)



6.3.2 CL triggered by glide formation: Luganda

It is possible to account for the Luganda glide formation plus CL case (10) in HS with mora-sharing and the FFC analysis as well.

The analysis will make use of the following additional constraints:

(85) *Constraints for the analysis of CL triggered by glide formation*

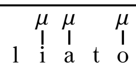
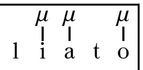
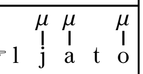
a. *VV
Assign one violation for every high vowel that is followed by another vowel.

b. Ident[cons]
Assign one violation for each segment in the input whose corresponding segment in the output has a different value of [consonantal].

*VV is the constraint drives glide formation. Ident[cons] is relevant because glides are assumed to be [-cons]. The FFC for the input /liato/ is [$\text{li}^{\mu}\text{a}^{\mu}\text{to}^{\mu}$]; I will assume that this form is syllabified as [li.a.to], but that assumption is not critical for the analysis.

In the first step, the [i] becomes a glide to avoid violating *VV:

(86) *First iteration: Glide formation*

	*VV	Max	Ident[cons]	Max[μ]	*μ/C	*Share	Dep-L[μ]	Max-L[μ]
a. 	*!							
b. ☞ 			*		*			

Candidate (a) is ruled out by the high-ranking constraint against sequences of vowels. Because there is no glide that corresponds to a low vowel, no candidate in which the /a/ has become a glide is considered. A candidate with a floating mora is ruled not considered; that is, because the vowel is associated with a mora, we cannot simply delete the /i/ altogether to avoid violating *VV. Moreover, notice that two logically possible candidates are ruled out by HS's gradualness requirement:

(87) *Impossible candidates*:

a. $/\mathrm{l}\ \overset{\mu}{\mathrm{a}}\ \mathrm{t}\ \overset{\mu}{\mathrm{o}}/$ (violates Max and Max[μ])

b. $/\mathrm{l}\ \mathrm{j}\ \overset{\mu}{\mathrm{a}}\ \mathrm{t}\ \overset{\mu}{\mathrm{o}}/$ (violates Ident[cons] and Max[μ])

Ruling these candidates out means that candidate (b) is the winning candidate at this stage. This might seem like a strange candidate given that there is a mora associated with what looks like an onset. It is likely, though, that this moraic and highly sonorant segment would be interpreted as part of the nucleus of the syllable. The /ja/ sequence is at least plausibly a diphthong.

Next, the mora associated with the /j/ is associated with the following vowel to avoid the violation of *μ/C. The output of the previous step is ruled out here by ranking *Share and Dep-L[μ], both of which are violated by candidate (c), below *μ/C. Candidate (c), which contains a non-moraic glide, is ruled out by a high ranking Max[μ]:

(88) *Second iteration: Mora sharing*

$\mathrm{l}\ \overset{\mu}{\mathrm{j}}\ \overset{\mu}{\mathrm{a}}\ \mathrm{t}\ \overset{\mu}{\mathrm{o}}$	*VV	Max	Ident[cons]	Max[μ]	*μ/C	*Share	Dep-L[μ]	Max-L[μ]
a. $\mathrm{l}\ \overset{\mu}{\mathrm{j}}\ \overset{\mu}{\mathrm{a}}\ \mathrm{t}\ \overset{\mu}{\mathrm{o}}$					*!			
b. $\mathrm{l}\ \mathrm{j}\ \overset{\mu}{\mathrm{a}}\ \mathrm{t}\ \overset{\mu}{\mathrm{o}}$				*!				
c. ☞ $\mathrm{l}\ \overset{\mu}{\mathrm{j}}\ \overset{\mu}{\mathrm{a}}\ \mathrm{t}\ \overset{\mu}{\mathrm{o}}$						*	*	

Finally, the mora is delinked from the glide altogether. This is possible because *Share is ranked above Max-L[μ]:

(89) *Third iteration: CL*

$\mathrm{l}\ \overset{\mu}{\mathrm{j}}\ \overset{\mu}{\mathrm{a}}\ \mathrm{t}\ \overset{\mu}{\mathrm{o}}$	*VV	Max	Ident[cons]	Max[μ]	*μ/C	*Share	Dep-L[μ]	Max-L[μ]
a. $\mathrm{l}\ \overset{\mu}{\mathrm{j}}\ \overset{\mu}{\mathrm{a}}\ \mathrm{t}\ \overset{\mu}{\mathrm{o}}$						*!		
b. ☞ $\mathrm{l}\ \mathrm{j}\ \overset{\mu\ \mu}{\mathrm{a}}\ \mathrm{t}\ \overset{\mu}{\mathrm{o}}$							*	

At this point, the derivation converges. There is no change to the CL form that better satisfies the constraint ranking. Because *VV penalizes only those two-vowel sequences that begin with a high vowel, lengthening is not predicted to occur in other sequences of vowels. That is, there is no motivation for turning the first vowel in a sequence of non-high vowels into a glide. Not coincidentally, it is also the cause that there is no glide that differs minimally from the non-high vowels. The FFC analysis, then, correctly derives the more complex case of CL derived from glide formation in Luganda as well.

6.3.3 More complex CL triggered by glide formation: Japanese

The Japanese CL triggered by glide formation in (4) can be analyzed exactly like the Luganda data presented in the previous section. Consider the input /bariumu/. The FFC for such an underlying representation will be /ba$^{\mu}$.ri.$^{\mu}$u$^{\mu}$.mu$^{\mu}$/, with moras associated with all vowels (There are no coda consonants in this form, so no moras are associated with a consonant). In the first stage of the derivation, /i/ becomes a glide to avoid violating a constraint on [iu] sequences:[17]

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[17] There is a question here of why the /u/ does not become a [w] instead. It seems likely that CodaCond is ranked highly enough to rule [bariwmu] out in favor of [barjumu].

(90) *First iteration: Glide formation*

μ μ μ μ b a r i u m u	*iu	Ident[cons]	Max[μ]	*μ/C	*Share	Dep-L[μ]	Max-L[μ]
a. μ μ μ μ b a r i u m u	*!						
b. ☞ μ μ μ μ b a r j u m u		*		*			

The faithful candidate in (90) is ruled out because it contains a disallowed /iu/ sequence. The winner, candidate (b), is a form that removes the offending sequence by changing the /i/ to its corresponding glide /j/.

Next, the mora associated with the [j] is associated with the following vowel to avoid violating *μ/C, as shown in (91). This might seem strange in that a mora is shared between an onset and the following nucleus. On the other hand, though, the [j] is in the process of being reanalyzed; at this intermediate stage in the derivation, it retains some of the properties of the vowel it used to be but does not yet have all of the properties of the onset it will become. It is likely that, in any language that would use this structure productively, the [j] would be reanalyzed as part of the nucleus.

(91) *Second iteration: Mora sharing*

μ μ μ μ b a r j u m u	*iu	Ident[cons]	Max[μ]	*μ/C	*Share	Dep-L[μ]	Max-L[μ]
a. μ μ μ μ b a r j u m u				*!			
b. μ μ μ b a r j u m u			*!				
c. ☞ μ μ μ μ b a r j u m u					*	*	

The faithful candidate in (91) is eliminated because the newly formed glide is associated with its own mora. This problem cannot be fixed by deleting the mora because Max[μ] is highly ranked, ruling out candidate (b). The winner, then, is a form in which the mora associated with that /j/ is shared with the preceding vowel. In the next step, the mora is delinked from the glide altogether:

(92) *Third iteration: CL*

μ μ μ μ b a r j u m u	*iu	Ident[cons]	Max[μ]	*μ/C	*Share	Dep-L[μ]	Max-L[μ]
a. μ μ μ μ b a r j u m u					*!		
b. ☞ μ μ μ μ b a r j u m u							*

Here, the faithful candidate (a) loses because *Share is ranked above Max-L[μ]. And because there is no change to this form that better satisfies the constraint hierarchy, the derivation will converge after this step. Again, this is exactly the result we would expect given the previous successful analysis of a similar phenomenon in Luganda.

What happens when we consider a similar form where the glide is ultimately lost, like /radiumu/ → [raʤuːmu] ‘radium’? It must be the case that the glide is formed and then fused with the preceding consonant due to some phonotactic constraint, otherwise it would also be lost in a form like [barjuumu]. Suppose, then, that there is a constraint *dj that assigns a violation to outputs containing this sequence. If underlying /dj/ sequences never surface as such, we would expect this constraint, like the constraint against [iu] sequences, to be undominated. The derivation of [raʤuːmu], then, would begin in much the same way as the derivation of [barjuːmu]. The FFC will be /ra$^{\mu}$.di$^{\mu}$.u$^{\mu}$.mu/, a syllabified form that has a mora associated with each vowel. The first step is exactly parallel to the first step in the derivation of [barjuːmu], as illustrated in (93)

(93) *First iteration: Glide formation*

μ μ μ μ r a d i u m u	*iu	Max	*dj	Ident[cons]	Max[μ]	*μ/C	*Share	Dep-L[μ]	Max-L[μ]
a. μ μ μ μ r a d i u m u	*!								
b. ☞ μ μ μ μ r a d j u m u			*	*		*			

The tableau in (93) shows that the two phonotactic constraints must be ranked with respect to one another; for glide formation to occur, it must be better for a form to include a /dj/ sequence than an /iu/ sequence. Notice, too, that a candidate that removes the mora from the /i/ is not considered because it violates the undominated (but not shown) constraint against non-moraic vowels. The winner, then, is candidate (b), which contains a moraic glide. The next iteration shows that Max must be ranked above *dj. Otherwise, it would be better to delete the /d/ to remove the offending /dj/ sequence:

(94) *Second iteration: Mora sharing*

μ μ μ μ r a d j u m u	*iu	Max	*dj	Ident[cons]	Max[μ]	*μ/C	*Share	Dep-L[μ]	Max-L[μ]
a. μ μ μ μ r a d j u m u			*			*!			
b. μ μ μ r a d j u m u					*!				
c. μ μ μ μ r a j u m u		*!	*			*			
d. ☞ μ μ μ μ r a d j u m u			*				*	*	

In (94), the faithful candidate, (a), loses because it violates *μ/C—the /j/ remains associated with its own mora. Candidate (b), which deletes the mora associated with the /j/ loses because it violates Max[μ]. Deleting the /d/ to satisfy *dj, as in candidate (c), is problematic because of high-ranking Max. This leaves candidate (d), with a shared mora, as the winner. Again, the mora-sharing in this step is exactly the same as the mora-sharing that happens in the derivation of [barjuːmu].

The next step, however, must be different. While the ultimate goal is a long vowel, it is not the case that we want to delete the /j/ that is associated with a shared mora. Instead, we want the mora to be delinked from the /j/, which should coalesce with the preceding /d/ to form the single consonant /ʤ/. Both processes cannot happen at once because each violates a separate faithfulness constraint. There are two logically possible ways to accomplish these two changes: disassociate the mora from the /j/, then fuse the /j/ with the preceding /d/; or fuse the consonants and then delete the mora. Coalescence of the the /d/ with a moraic /j/ poses a problem, though. The resulting syllable, would have a mora partially associated with its onset. Such syllables are not well-formed, and it is likely that Gen does not generate them. It must be the case, then, that coalescence happens only after the /j/ is delinked from its mora. The fact that the de-linking happens at all means that Max-L[μ] must be ranked low:

(95) *Third iteration: Lengthening*

μ μ μ μ r a d j u m u	*[iu]	Max	*dj	Ident[cons]	Max[μ]	*μ/C	*Share	Dep-L[μ]	Max-L[μ]
a. μ μ μ μ r a d j u m u			*				*!		
b. μ μ μ μ r a d u m u		*!							
c. ☞ μ μ μ μ r a d j u m u			*						*

In (95), the faithful, mora-sharing candidate loses because it violates *Share. Deleting the /j/ to avoid violating *dj runs afoul of Max, eliminating candidate (b). The winner is a candidate that has a long vowel from which the /j/ has been deleted. The next step should be coalescence of the /dj/ sequence. If we assume that segments in a syllable onset can never be associated with a mora and that this restriction is built into GEN, coalescence may only occur after the /j/ has been divorced from its mora. In other words, only after glide formation, mora-sharing, and vowel lengthening have occurred can coalescence take place. This means that the ranking of UNIFORMITY is underdetermined; as long as it is dominated by *dj, lengthening will occur late in the derivation. This step is illustrated in (96) below:

(96) *Fourth iteration: Coalescence*

μ μ μ μ r a d j u m u	*[iu]	MAX	*dj	IDENT[CONS]	MAX[μ]	*μ/C	*SHARE	DEP-L[μ]	MAX-L[μ]	UNIF
a. r a d j u m u										
b. ☞ r a d ʒ u m u										*

The fact that it is possible to analyze these Japanese data in the FFC framework shows that the analysis extends to quite complex derivations involving both CL and other segmental processes. The derivation above includes glide formation, CL, and coalescence; all of which must be ordered with respect to one another. It is certainly a strength of the analysis that it can account for these interactions between CL and other processes. Admittedly, though, this is the most stipulative of the case studies presented so far—it relies on the potentially unfalsifiable claim that GEN does not allow candidates that have moras even partially associated with onset segments. If moraic theory is correct, though, no language makes use of surface forms that have moraic onsets. Given the assumption that all intermediate representations are possible outputs in some language, this in turn means that GEN should not be able to produce such candidates.

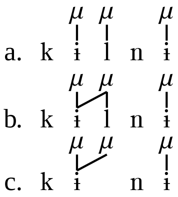
In this subsection, I have shown that a variety of complex and unusual types of canonical CL can be analyzed satisfactorily using a HS derivation that begins with a FFC. In Section 6.4, I turn to the predictions that this analysis makes for forms in which no lengthening occurs.

6.4 Predictions of the analysis

6.4.1 Predictions of the FFC analysis

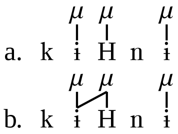
If we believe that each intermediate representation in a HS derivation is a valid surface form in some language, the FFC analysis and the gradual deletion analysis make different predictions about the nature of CL and about typologically possible surface forms. The predictions of the FFC analysis are relatively straightforward. First, consider the winning candidates after each step in the derivation (given in (97) below for convenience). The FFC and the input to the first step is (97a), a form with a moraic coda consonant. Forms like this occur in any language that has quantity-sensitive prosodic structure. The input to the second pass of the derivation is (97b); the mora-sharing structure is attested as a surface form for closed syllables in languages like Malayalam and Levantine Arabic (Broselow et al., 1997). And, of course, the CL form in (97c) is attested in languages that have long vowels in surface forms.

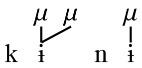
(97)



We can see, then, that the derivation required for the FFC analysis consists of a sequence of attested surface forms. For each of these forms, there is a constraint ranking that will cause the derivation to converge on that form. Because each of the inputs are possible surface forms, the predictions of the factorial typology seem plausible. Recall that this is not true of the gradual deletion analysis, which posits an intermediate representation that contains a mysterious, sonorant placeless consonant:

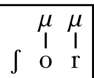
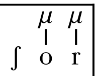
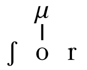
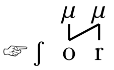
(98)



c. 

The analysis also makes predictions about the moraic structure of non-CL forms in languages that have CL. The first step in the derivation—going from an input with a moraic coda consonant to a form in which that mora is shared between the coda and the following vowel—does not depend on the identity of the consonant. It is only after that mora is shared that we see the effect of *l/CODA. Therefore, words that contain coda consonants other than l are also predicted to have mora-sharing structures. We can see this by applying the analysis to a form that does not contain a l like /ʃor/ 'house':

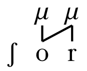
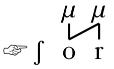
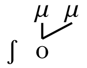
(99) *First iteration: Mora sharing*

	WBP	MAX[μ]	*l/CODA	MAX	*μ/C	DEP-L[μ]	*SHARE
a. 					*!		
b. 	*!	*					
c. ☞ 						*	*

As in the derivation of CL, the derivation of a non-CL form begins with a FFC: a syllabified and moraically specified form. In this case, the coda consonant is associated with a mora in the input to the first iteration. The faithful candidate loses because *μ/C is ranked above DEP-L[μ] and *SHARE. This means that the winning candidate, (99c), is one in which the mora is shared.

After this stage, the derivation will converge because there is no change to the input that better satisfies the constraint hierarchy. Specifically, the coda consonant will not be deleted because the constraint that motivates deletion in the CL case does not apply (*i.e.*, the /r/ will not be deleted to satisfy *l/CODA):

(100) *Second iteration: No CL*

	WBP	MAX[μ]	*l/CODA	MAX	*μ/C	DEP-L[μ]	*SHARE
a. ☞ 							*
b. 				*!			

The analysis as it stands, then, predicts the closed-syllable lengthening exists in Komi Ižma, just as it does in Malayalam and Levantine Arabic. Shaw (2007) cites evidence from several sources (Igushev, 1972; Sakharova and Sel'kov, 1976; Terent'ev, 1970) that there is in fact closed-syllable lengthening in this dialect, including experimental evidence suggesting that vowels in closed syllables are longer than vowels in open syllables but shorter than the long vowels derived from CL. This pattern is exactly what the FFC analysis predicts: vowels in open syllables are associated with one mora, vowels in closed syllables are associated with one and a half moras, and vowels in CL syllables are associated with two moras. These predictions are borne out by the phonological facts.

The bolder prediction, of course, is that all languages that have synchronic CL will exhibit this closed-syllable lengthening. Ideally, we would like to see phonetic evidence from colloquial Turkish and other languages that would support this prediction. Alternatively, it is possible that, while the mora-sharing structure is utilized in these languages, the phonetic realization of that structure is different across languages. In more concrete terms, the phonetics of a particular language might disallow vowels of intermediate length, interpreting only those vowels that are associated with two whole moras as long. Vowels associated with a mora and a half could, with this constraint, be pronounced the same as short vowels. This phonetic hypothesis would leave us in an uncomfortable theoretical position in that the association between the vowel and the second mora is present in the phonological representation but has no consequences for the pronunciation of that form. Without phonetic evidence from more languages that have CL, though, it is impossible to know what the typological implications of mora-sharing are.

6.4.2 Consequences of the FFC

If we assume that the input to the derivation is a syllabified form that includes a complete moraic structure, it is possible that the gradual component is not needed. In other words, beginning with a FFC allows the rest of the "derivation" to proceed as in classic OT, with Gen not restricted by gradualism. Recall that Richness of the Base posed the biggest obstacle facing a classic OT analysis. Beginning the derivation with a FFC effectively neutralizes any non-contrastive differences in underlying forms. More specifically, because the FFC always has a mora associated with the coda consonant, the CL candidate is no longer harmonically bounded by a candidate that has deletion but no lengthening.

To illustrate, consider again the FFC for the Komi Ižma word /kɨlnɨ/. All of the candidates that were considered over the course of the FFC derivation can be eliminated in a parallel analysis as well:

(101) *Parallel evaluation (Komi Ižma): CL*

μ μ μ k ɨ l n ɨ	WBP	*Float	Max[μ]	*l/Coda	Max	*μ/C	Dep-L[μ]	Max-L[μ]	*Share
a. μ μ μ k ɨ l n ɨ				*!		*			
b. μ μ μ k ɨ l n ɨ				*!			*		*
c. μ μ k ɨ l n ɨ	*!		*	*					
d. μ μ μ k ɨ n ɨ		*!			*				
e. μ μ k ɨ n ɨ			*!		*				
f. μ μ μ k ɨ n ɨ					*		*	*	
g. ☞ μ μ μ k ɨ n ɨ					*		*	*	

Here, all of the non-CL candidates (a-e) are ruled out by the high-ranking constraints WBP, *Float, Max[μ], and *l/Coda. The desired winner, candidate (g) violates only the lower-ranked constraints Max (deletion of /l/), Dep-L[μ] (disassociation of mora from coda consonant), and Max-L[μ] (association of mora with lengthened vowel). While candidate (f), in which the vowel in the following syllable has been lengthened, incurs the same set of violations, it could easily be ruled out by constraints that penalize the disassociation and re-association of moras from syllables. Because the mora that was originally associated with the coda consonant has moved to the following syllable in candidate (f), that form must incur violations of the constraints Dep-L[σ] and Max-L[σ].

The same argument can be made for the Tehrani Farsi lengthening triggered by loss of /ʔ/ and /h/, as illustrated in (102) below. [18]

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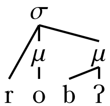
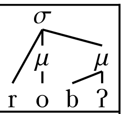
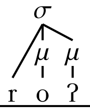
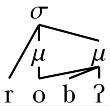
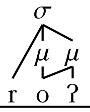
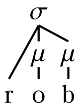
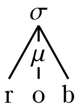
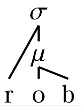
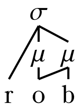
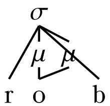
[18] This is also true of Japanese lengthening triggered by glide formation, but the tableau has been omitted for reasons of space.

(102) *Parallel evaluation (Tehrani Farsi): CL*

	*μ/[obs]	Max[μ]	*ʔ/Coda	Max	*μ/C	Dep-L[μ]	*Share	Max-L[μ]
a. 			*!		*		*	
b. 			*!	*	*			
c. 			*!			*	*	
d. 			*!	*		*	*	
e. 	*!			*	*			
f. 		*!		*				
g. 		*!		*		*	*	
h. 				*		*!		
i. ☞ 				*		*		*

In (102), all of the candidates (a-d) that retain the /ʔ/ are eliminated by *ʔ/Coda. Candidate (e), which deletes the /ʔ/ but leaves the /b/ associated with its own mora, is ruled out by *μ/[obs]. Those candidates that attempt to avoid the violation of *μ/[obs] by deleting the mora associated with the coda (f-g) run afoul of Max[μ], which is also highly ranked. The competition, then, comes down to candidates (h) and (i). Both violate Max because the /ʔ/ has been deleted and Dep-L[μ] because the vowel has been lengthened via association with the second mora. But while candidate (h) violates *Share because a mora is shared between the coda consonant and the preceding vowel, the CL candidate (i) instead incurs a violation of the lower-ranked Max-L[μ] (because the /b/ has been disassociated from its mora). Therefore, the CL candidate is correctly predicted to emerge as the output. In this case, too, the FFC has guaranteed that the input to the constraint ranking has a moraic structure that is compliant with the language's principles of syllabification; Richness of the Base has been neutralized and the CL candidate is no longer harmonically bounded, meaning that the multi-step HS derivation is not strictly necessary.

While an analysis that combines classic OT with a FFC is certainly possible, it goes against the spirit of Richness of the Base—that principle requires consideration of all possible underlying representations, not just the best one. Classic OT does not exploit the distinction between markedness constraints (which, even in HS, may be violated at will) and faithfulness constraints the way that HS does. In HS, it makes sense to talk about a FFC because the number of faithfulness constraints violated by a given candidate plays a crucial role in defining the framework itself. Furthermore, abandoning HS in the absence of evidence that the theory is wrong would not be prudent. HS has been argued to be independently necessary for the analysis of a number of disparate phenomena: cluster simplification

(McCarthy, 2008a), epenthesis (Elfner, 2009), foot building (Pruitt, 2010), nasal assimilation (McCarthy, 2008a), positional faithfulness (Jensey, 2009), syllabification (Elfner, 2009) syncope (McCarthy, 2008b), variation (Kimper, 2011) and others.

6.4.3 Limitations of the analysis

One problem for this HS analysis of CL is that it can account for only local interactions—those in which the trigger is adjacent to the lengthened segment (or, at most, in the coda of the same syllable as the lengthened vowel). That property may actually be a strength of the analysis in that the vast majority of canonical CL involves a relationship between a coda consonant and an immediately preceding vowel.

The mora-sharing structure required by HS's commitment to gradualism means that the trigger and the lengthened segment must be in the same syllable; the crossed association lines necessary to create a mora-sharing structure across syllables could not be generated by GEN. This means that any example of CL that appears to cross syllable boundaries must be analyzed in some other way. The phenomena left to account for include CVCV CL, illustrated in (103a). In CVCV CL, apocope of the the second vowel triggers lengthening of a vowel in the previous syllable. Similarly, so-called "double flop" CL (103b) is also unaccounted for by a mora-sharing analysis.

(103) a. /ɳi-ɳə/ → [ɳiːɳ] 'heads' (Lama; Kavitskaya 2002, p. 166)
b. *odwos → oːdos 'threshold' (Ancient Greek; Hayes 1989, (19))

It is likely that CVCV CL is really conservation of some level of prosodic structure higher than the mora. Before CVCV CL applies, the underlying representation is a bimoraic foot. After lengthening, the output is also a bimoraic foot. This fact suggests that, in at least some cases, the lengthening is motivated by the language's desire to maintain bimoraic feet and/or bimoraic minimal words. If the motivation for lengthening is not syllable-internal, it cannot be analyzed via mora-sharing.

The fact that the analysis cannot account for these cases is not a fatal problem for the analysis presented above for two reasons. First, CVCV CL and double flop CL are not intrasyllabic processes; the fact that they are called "CL" is perhaps misleading given that they can reasonably taken to be different phenomena from canonical CL. Secondly, and perhaps more convincingly, CVCV CL and double flop CL are almost always phonologized remnants of a diachronic change. The double flop in (103b) was a diachronic change that took place in particular dialects of Ancient Greek. And Kavitskaya (2002) argues that CVCV CL is not likely to be a productive synchronic process because the trigger is not necessary recoverable in the synchronic phonology. The FFC analysis of CL is intended primarily to account for synchronic alternations; it is not necessarily a failure of the analysis if it cannot account for a particular diachronic change.

Similarly, the analysis presented above relies crucially on the assumption that only the loss of moraic segments can trigger CL. It has been claimed (Beltzung, 2008; Kavitskaya, 2002; *i.a.*) that some languages have CL triggered by the loss of an onset. These putative counterexamples to the moraic theory of CL include dialects of Italian and Greek. The trigger in question, though, is always a highly sonorant segment, and Kiparsky (2010) argues convincingly that these segments (/r/ in Samothraki Greek) are reasonably interpreted as part of the nucleus of the syllable before it is deleted. If this is the case, these are not true counterexamples, and the FFC analysis could countenance them just as well as the canonical cases by assigning a mora to the trigger in the FFC.

7 Conclusion

7.1 Summary of the analysis

In this paper, I hope to have demonstrated that a HS analysis of CL is sufficient only if it begins with a syllabified and moraically specified version of the input. Neither classic OT nor OT-CC can provide a satisfactory account of the opacity of CL while at the same time allowing for the variety of underlying representations allowed by Richness of the Base. CL is also problematic for HS itself. If gradual deletion of consonants is not assumed, a ranking paradox arises. The trigger must be present in the derivation long enough to be associated with a mora, so MAX must be ranked above the constraint that motivates deletion at the beginning of the derivation. At a subsequent stage, however, the consonant must delete. For the deletion to occur, the constraint that motivates deletion must be ranked above MAX. This ranking paradox is related to Richness of the Base in that it cannot be guaranteed that the trigger is associated with a mora and to syllable structure in that it is impossible to know whether the trigger will surface in coda or onset position.

Gradual deletion of consonants appears to be a way out of this problem because it forces the consonant that will be deleted to remain in the derivation long enough for the requisite moraic structure to be built. Several problems with this approach were identified in Section 5.3, though. First, it is not clear that the intermediate representations proposed are pronounceable or are possible outputs in any language. And in the general case it is not possible to delete a consonant without first deleting its place features. This restriction amounts to imposing an order of violations on the derivation, something that is theoretically undesirable. Second, unless redundancies in the featural specifications of laryngeal consonants are posited, the gradual deletion approach cannot account for CL triggered by the loss of a laryngeal consonant. Placeless consonants should be deleted in a single step, but this fell-swoop deletion does not allow the deleted consonant to remain long enough to be associated with a mora.

These failed analyses contrast with the FFC analysis presented in Section 6. Under that approach, the derivation begins with a syllabified and moraically specified form. The FFC is motivated by the fact that neither syllabification nor the insertion of positional moras violate any faithfulness constraint. If prosodic structure up to the syllable is built before any segmental changes take place, it can be guaranteed that the trigger is associated with a mora before it is deleted. CL crucially makes reference to syllable structure, so it can only be analyzed with respect to a syllabified form. Beginning the derivation with a FFC allows this to happen and, consequently, allows for the analysis of a variety of types of CL—those caused by deletion and glide formation, as well as those caused by deletion of a tautosyllabic but not adjacent consonant. The empirical coverage of the FFC analysis makes it superior to the gradual deletion analysis. Like any derivational mora-sharing analysis of CL, the FFC analysis predicts that languages with CL will also have closed syllable lengthening. Finally, it is a strength of the analysis that it is limited to intrasyllabic interactions. Cross-syllabic CL is both very rare and almost exclusively limited to diachronic change.

The FFC analysis is in many ways similar to autosegmental derivational analyses of CL. Syllable structure is built without penalty at every step in the derivation. The biggest difference is that instead of a stage with an unassociated mora, the FFC analysis posits mora-sharing. But as we saw in the discussion of Japanese CL triggered by glide formation, the FFC analysis has the effect of rule ordering. The derivation of [raʤuːmu] requires glide formation, mora-sharing, vowel lengthening, and coalescence to occur, in that order. Where a traditional derivational analysis would stipulate that the relevant rules apply in that particular order, the order of changes in a HS derivation is determined by the constraint ranking. That is, the same principles that govern the output of the phonology also govern the order in which gradual changes are made to the underlying representation.

We have seen that the syllabification and moraic structure are necessary prerequisites for the analysis of CL. This is a property common to both the FFC analysis and traditional derivational analyses. It might be possible to eliminate the need for the FFC in constraint-based phonology if a stratal approach were used. Re-ranking constraints between strata could eliminate the ranking paradox between MAX and the constraint that motivates deletion of the trigger. The problem with this approach is that there is no reason to posit separate strata during the course of the derivation of CL. CL can occur morpheme-internally, as in Turkish, and so does not require a distinction between morpheme- and word-level strata. The FFC approach is a better option because it requires neither constraint re-ranking nor separate levels of analysis. As is, the FFC approach accounts for a variety of canonical CL phenomena in a manner that is very similar to precedented and accepted derivational models of CL.

7.2 Directions for future research

Given that the HS analysis predicts closed-syllable lengthening in languages that have CL, there ought to be phonetic evidence that will bear on the correctness of the analysis. While there is evidence that vowels in closed syllables are longer than vowels in open syllables in Komi Ižma, I know of no such evidence in the other languages discussed in this paper. Closed-syllable lengthening is a counterintuitive and relatively rare phenomenon, and evidence that it is prevalent in languages that have CL would significanly understand our understanding of moraic theory.

To that end, it is important to supplement this theoretical work with experimental data. The analysis presented here predicts that colloquial Turkish should have longer vowels in closed syllables than in open ones, and it is worth measuring to see whether this prediction is borne out. Of particular interest, though, is the Tehrani Farsi pattern where the deleted trigger and the lengthened segment are in the same syllable but not necessarily adjacent. Several questions arise from these data, including whether speakers exhibit evidence of closed-syllable lengthening. When CL applies to an underlyingly doubly-closed syllable, is the length of the resulting vowel the same length as the vowel that results from CL in a syllable that originally contains only one coda consonant? Furthermore, the Tehrani Farsi analysis predicts that moras should be able to be shared three ways between a vowel and each of two coda consonants. Is this a reasonable prediction? To answer this question, we would need to look for languages that have subtle differences in vowel length between closed and doubly-closed syllables. Whether such languages exist is an empirical question that deserves future attention.

An unrelated, but equally necessary, avenue for future research is to investigate different types of CL. In this paper, I have focused only on cases where the loss of a consonantal segment triggers vowel lengthening. In other cases, deletion of a consonant triggers gemination of an adjacent consonant; this pattern occurs in Eastern Andalusian dialects of Spanish (Gerfen, 2001) and in other languages. This phenomenon is very similar to the canonical cases of CL analyzed here in that deletion of one moraic segment results in an additional mora being associated with an adjacent segment. It is less clear, though, that the mora-sharing approach generalizes to examples like the one given in (104), as the segments in question are not in the same syllable. It is, of course possible that there is some other explanation for this phenomenon (perhaps one involving assimilation), but it looks quite similar to canonical CL. That said, I leave to future research whether the FFC analysis exends straightforwardly to compensatory gemination.

(104) /boske/ → [bok.ke] 'forest' (Gerfen 2001, (3))

Compensatory lengthening is an intuitive but diverse phenomenon, and it is my hope that the analysis presented here accounts for similar effects in a variety of languages.

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