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How to delete

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Abstract

Using data from Arabic and other languages, this chapter argues that segmental deletion processes are gradual in the sense that segments are lost through attrition rather than all at once. The argument is framed within Harmonic Serialism, a derivational version of Optimality Theory that allows deletion processes to be decomposed into successive reduction steps.

Introduction

How do segments delete? Does the entire segment disappear in a single operation? Or does the segment disappear gradually because multiple operations have taken away its structure piece-by-piece? This chapter will argue that segmental deletion is a gradual process that occurs through successive reduction operations.

This argument is set within Optimality Theory (OT) (Prince & Smolensky, 1993/2004), specifically within a derivational version of OT called Harmonic Serialism (HS) (McCarthy, 2010, and references cited there). In OT, the operational component is called GEN, and thus the argument of this chapter is that GEN includes an operation that deletes parts of segments, but no operation that can delete the multiple parts of a structurally complex segment simultaneously. Evidence will be drawn from Arabic and other languages.

This chapter is laid out as follows. I begin by explaining what HS is and how it offers a new perspective on deletion processes. I also review evidence that an HS approach to deletion is the right one. I then turn to Arabic, discussing various consequences of this approach for the analysis of Arabic (classical and colloquial), with occasional forays into other languages. The chapter concludes with an overview of some of the questions that have been raised by this project but not yet answered.

About Harmonic Serialism

OT has been standardly understood as a parallel model of optimization. An input is submitted to GEN, which can apply multiple operations in parallel to create each of its candidates. It therefore generates candidates that can differ from each other and from the input in many ways at once. For instance, the candidate set from Classical Arabic /fʕal/ 'do!' is {fʕal, ifʕal, ʔifʕal, ʔifʕil, ʔiftal, …}. This rich, diverse candidate set is submitted to the EVAL component – that is, the grammar – which selects the optimal candidate [ʔifʕal] as its final output.

In HS, however, GEN can only apply one operation to form each candidate. In the Classical Arabic case, this means that the final output [ʔifʕal] is not in the initial candidate set of /fʕal/ because it requires two operations, epenthesis of [ʔ] and epenthesis of [i]. HS deals with this seeming limitation by looping the output back into GEN for another pass: /fʕal/ →$_{\text{GEN}}$ {fʕal, ifʕal, fʕil, …} →$_{\text{EVAL}}$ [ifʕal] →$_{\text{GEN}}$ {ifʕal, ʔifʕal, ifʕil, …} →$_{\text{EVAL}}$ [ʔifʕal]. The derivation terminates when it *converges*: the most recent output of EVAL is identical to the most recent input to GEN, so no further changes are possible. The tableaux in (1)-(3) illustrate.[2] (The constraint *#CC prohibits initial clusters; ONSET is violated by vowel-initial words; and DEP militates against epenthesis.)

(1) /fʕal/ → [ʔifʕal] in HS Step 1

/fʕal/	*#CC	ONSET	DEP
a. → ifʕal		*	*
b. fʕal	*!		

(2) /fʕal/ → [ʔifʕal] in HS Step 2

ifʕal	*#CC	ONSET	DEP
a. → ʔifʕal			*
b. ifʕal		*!	

(3) /fʕal/ → [ʔifʕal] in HS Step 3

ʔifʕal	*#CC	ONSET	DEP	
a. → ʔifʕal				*convergence*
b. ʔifʕali			*!	

From this HS perspective, the question "How do segments delete?" reduces to the question "What are the deletion operations in GEN?" I will argue that there is no operation that can, in a single step, delete any segment regardless of its structural complexity.

Deletion as Gradual Reduction: An Example[3]

It has been observed that simplification of medial consonant clusters normally deletes the first consonant rather than the second (Steriade, 2001/2008; Wilson, 2001):[4] /patka/ → [paka], *[pata]. Under standard assumptions, parallel OT has no explanation for this asymmetry. As shown in (4), deletion of [t] *or* [k] equally satisfies the constraint NO-CODA, which prohibits syllable-final consonants. (The period/full stop marks the syllable boundary.)

(4) Parallel OT does not explain coda deletion asymmetry

/patka/	NO-CODA	MAX
a. → pa.ka		*
b. → pa.ta		*
c. pat.ka	*!	

HS, in contrast, offers the possibility of decomposing consonant deletion into a reduction step followed by deletion of the reduced segment: /patka/ → [paʔ.ka] → [pa.ka]. This analysis can account for the asymmetry because reduction of codas is a well-attested phonological process, while reduction of onsets is not. If reduction of /t/ or /k/ is a necessary prelude to deletion, then the asymmetry follows from the fact just observed: codas reduce but onsets do not.

Formally, let us assume a simplified feature geometry (Clements, 1985; McCarthy, 1988) in which consonants are headed by their Place node. GEN provides an operation that can delete any node, including the Root node, but it cannot delete a headed (i.e., Place-bearing) Root node. From this assumption about GEN, it follows that deletion of /t/, /k/, or any other unreduced consonant must proceed in two steps: /patka/ → [paʔ.ka] → [pa.ka]; /patka/ → [pat.ʔa] → [pa.ta]. For a derivation to be possible in HS, there must be some constraint ranking under which every step of the derivation is optimal. There is a ranking that will produce the first of these derivations, but there is no ranking that will produce the second. The reason why the first derivation is possible is that codas are poor licensers of Place, an observation that is embodied in the constraint CODA-COND, which is violated by Place in coda position (Goldsmith, 1990, pp. 123-128; Ito, 1989). Ranked above the faithfulness constraint MAX(Place) and the markedness constraint HAVE-PLACE that is violated by Place-less consonants, CODA-COND compels deletion of Place in the coda /t/, yielding [ʔ]. This is shown in step 1 of the derivation in (5).

(5) Step 1 of /patka/ → [paʔ.ka] → [pa.ka] in HS

/patka/	CODA-COND	HAVE-PLACE	MAX (Place)	MAX (Root)
a. → paʔ.ka		*	*	
b. pat.ʔa	*!	*	*	
c. pat.ka	*!			

At Step 2 (6), the glottal stop coda then deletes, because HAVE-PLACE dominates MAX(Root), the faithfulness constraint that would protect glottal stop's remaining structure.

(6) Step 2 of /patka/ → [paʔ.ka] → [pa.ka] in HS

paʔ.ka	CODA-COND	HAVE-PLACE	MAX (Place)	MAX (Root)
a. → pa.ka				*
b. paʔ.ka		*!		

Finally, the derivation converges on [pa.ka] at Step 3 (7), since no further harmonic improvement is possible.

(7) Step 3 of /patka/ → [paʔ.ka] → [pa.ka] in HS

[pa.ka]	CODA-COND	HAVE-PLACE	MAX (Place)	MAX (Root)	
a. → pa.ka					*convergence*
b. pa.ʔa		*!	*!		

There are several important points to note about the HS derivation in (5)-(7). First, [pa.ka] and [pa.ta] are not among the candidates at Step 1, and [pa.ta] is not among the candidates at Step 2. This follows from our assumption about GEN: it does not have an operation that can perform the single-step mappings /t/ → Ø or /k/ → Ø. Assumptions like this are critical to many explanations in HS. Second, the Step 1 tableau shows that [pat.ʔa] is harmonically bounded by [pat.ka]. Harmonic bounding means that [pat.ʔa] can never win under any ranking, and so a derivation that transforms /patka/ into [pa.ta] is impossible. Harmonic bounding of [pat.ʔa] follows from an assumption about the constraint component CON: it does not have a constraint "ONSET-COND" parallel to CODA-COND. This asymmetry is a substantive fact about the phonology of codas and onsets, for which see Steriade (2001, 2001/2008). Third, the fact that deletion of [ʔ] requires just a single step (Step 2 in (5)) predicts that there should be languages in which only [ʔ] (or [h]) is deleted from coda position. In Classical Arabic, for example, there is a dissimilation process affecting /ʔVʔ/: /ʔa-ʔθar-a/ → [ʔa:θara] 'he preferred'. Other segments do not delete in a similar context: /ta-truk-u/ → [tatruku], *[ta:ruku] 'she relinquishes'. One way to analyze this phenomenon is to assume a general dissimilatory pressure (cf. the root co-occurrence constraints studied by Greenberg (1950) and others), but only [ʔ] can be deleted in a single step.

Discussion

The ideas about consonant cluster simplification in HS developed in the previous section have four interesting consequences for phonology in general.

First, segments with less structure are more susceptible to deletion than more complex segments. This follows from our assumption about GEN: its operations are limited to deleting pieces of structure one at a time, until the remnant is so reduced in complexity that it can be deleted all at once. Hence, /t/ is less susceptible to deletion than /ʔ/, as shown by the /ʔa-ʔθar-a/ example at the end of the last section. (Compare the notion of "cheap segments" in Gouskova (2003).)

Second, every context in which structurally complex segments are observed to delete is also a context in which these segments may reduce but not delete.[5] This is a claim about language typology: deletion contexts in language A may be reduction contexts in language B. In A, HAVE-PLACE dominates MAX(Root), as in (6), but the ranking is the other way around in B.

Third, deletion of complex segments entails deletion of simpler segments. A grammar like (5) that produces the derivation /patka/ → [paʔ.ka] → [pa.ka] will also produce the derivation /paʔ.ka/ → [pa.ka].

Fourth, segments have internal structure that differs in complexity. This assumption has been pervasive throughout the discussion thus far. It is practically a truism of contemporary phonological theory, but still worth noting.

The balance of this chapter will be devoted to exploring these four consequences of HS in greater detail.

Structure and Deletability

Segments with more internal structure are predicted to be more resistant to deletion than segments with less internal structure. This follows from our assumptions about HS's GEN: it cannot delete all of a complex segment's structure at once. Any constraint ranking that will yield a derivation that deletes a complex segment will also yield a derivation that deletes a simpler one, because the simpler segment is a step along the way of the derivation that deletes the complex segment. (Recall the point about how a grammar that produces /patka/ → [paʔ.ka] → [pa.ka] will also produce the derivation /paʔ.ka/ → [pa.ka].)

This aspect of the theory offers a new insight into a well-known problem in Arabic dialect typology: the distinction between the differential and non-differential dialects (Angoujard, 1990; Broselow, 1992; Cantineau, 1939; Farwaneh, 1995; Gouskova, 2003). There is even evidence that Classical Arabic was differential: loss of medial short vowels *metri causa* in verse appears to have been limited to /i/ and /u/ (Wright, 1971, pp. 384-385); and there is some reason to think that the loss of final short vowels in the development of modern Arabic dialects affected /i/ and /u/ first (Birkeland, 1940).

In differential dialects, such as Cairene in (8), the high vowels /i/ and /u/ are susceptible to syncope, but the low vowel /a/ is not. In non-differential dialects, such as Yemeni in (9), all three vowels are susceptible to syncope.

(8) Differential Dialect: Cairene (J. Watson, 2002, p. 74)

/tˤardi k*i*bi:r/	tˤardi kbi:r	'my parcel is big'
/ʕandi ħ*u*ma:r/	ʕandi ħma:r	'I have a donkey'
/tˤardi t*a*wi:l/	tˤardi t*a*wi:l	'my parcel is long'

(9) Non-differential Dialect: Yemeni (J. Watson, 2002, p. 78)

/tiʃti t*i*si:r/	tiʃti tsi:r	'she wants to go'
/gadu k*u*bur/	gadu kbur	'he has grown up'
/ʕa:di r*a*ɟamat/	ʕa:di rɟamat	'she has just thrown'

Following many particle, element, and underspecification theories of vowel representation (e.g., Archangeli, 1988; Clements, 1991; Schane, 1984; van der Hulst, 1989), we may assume that low vowels have more structure than high vowels, and the reduced vowel [ə] has no internal structure at all. For concreteness, I will adopt the representations in (10), though no details are truly crucial except that [a] has more structure than [i] or [u], and [i] and [u] have more structure than [ə].

(10) Vowel Representations

/a/ [Color], [Open]

/i, u/ [Color]

/ə/ [ ] (bare Root node)

As usual in OT, it is not enough to have explicit assumptions about representations; assumptions about constraints are also necessary. Reduction processes like syncope are an effect of constraints against structure, which may be contextual or non-contextual. To avoid a digression into questions about the syncope context (for which see Gouskova (2003) and McCarthy (2007), *inter alios*), I will simply refer to it as "Weak" in formulating the syncope constraints. There are two constraints that militate against the vowel features [Color] and [Open] in the Weak context. Categorical $*V_{WEAK}$-CAT in (11) is violated once if a vowel in the Weak context bears the features [Color], [Open], or both. It is therefore violated once by each of the vowels in (10) except for [ə].

(11) $*V_{WEAK}$-CAT

Assign a violation mark to every vowel in the Weak context that bears the features [Color] and/or [Open].

There is also a gradient version of this constraint in (12) that assigns two violation marks to [a] because it has both [Color] and [Open], but only one violation mark to the high vowels and none to [ə].

(12) $*V_{WEAK}$-GRAD

Assign a violation mark for every instance of [Color] or [Open] in the Weak context.

In addition to these constraints against featural structure, there is also a constraint against the total absence of featural structure in a vowel (12). It is violated by the vowel [ə].

(13) *[ ]

Assign a violation mark for every instance of the featureless vowel [ə].

In HS, far more so than in standard OT, it is important to be explicit about the assumptions about GEN, because the typology that emerges from a constraint set in HS is as dependent on the operations in GEN as it is on the constraints in CON. I assume that GEN includes an operation that deletes vowel features and bare vowel root nodes, but only one at a time. From this assumption, it follows that the only way to delete /a/ is with the three-step derivation /a/ → [i] → [ə] → Ø. The vowels /i/ and /u/ can be deleted in two-step derivations /i/ → [ə] → Ø. The vowel schwa deletes in a single step, because it has no internal featural structure, only a bare root node.

Any step in which structure is deleted violates the faithfulness constraint MAX.

We now have the resources in place to analyze the distinction between differential and non-differential dialects. In non-differential dialects, the feature-counting constraint *V_{WEAK}-GRAD dominates both the markedness constraint *[ ] and the faithfulness constraint MAX. The tableaux in (14) and (15) show the steps in the derivation of /i/ syncope in a non-differential dialect. (Throughout this discussion, the vowels are assumed to be in the Weak context that conditions reduction and syncope.) At Step 1, /i/ reduces to [ə] because *V_{WEAK}-GRAD dominates both *[ ] and MAX. Further reduction to Ø is not an option at this step – it isn't even a candidate – because GEN is limited to deleting a single structural element at a time, while /i/ has two structural elements, [Color] and a root node. (The categorical constraint *V_{WEAK}-CAT is shown as separated from the rest of the tableau because it is not visibly active in the non-differential dialects and hence is unrankable with respect to the other constraints.)

(14) Non-differential dialect deletion of high vowels Step 1

i	*V_{WEAK}-GRAD	*[ ]	MAX	*V_{WEAK}-CAT
a. → ə		*	*	
b. i	*!			*

At Step 2 in (15), however, Ø is a candidate, because schwa's bare root node can be deleted in a single step. The candidate Ø is optimal because the constraint that schwa violates, *[ ], dominates MAX.

(15) Non-differential dialect deletion of high vowels Step 2

ə	*V_{WEAK}-GRAD	*[ ]	MAX	*V_{WEAK}-CAT
a. → Ø			*	
b. ə		*!		

The derivation in (14) and (15) converges at Step 3 because Ø perfectly satisfies *V_{WEAK}-GRAD, so no further harmonic improvement is possible.

The tableaux in (16)-(18) show how the vowel /a/ is deleted in a non-differential dialect. At the first step (16), /a/ loses its [Open] feature, reducing to [i]. This is required by *V_{WEAK}-GRAD, which is violated once for every feature that a vowel bears. Further reduction to [ə] or Ø is not yet an option at Step 1, given our assumptions about the operations in GEN.

(16) Non-differential dialect deletion of low vowels Step 1

a	*V$_{WEAK}$-GRAD	*[ ]	MAX	*V$_{WEAK}$-CAT
a. → i	*		*	*
b. a	**!			*

At Step 2 (17), *V$_{WEAK}$-GRAD is still active, compelling deletion of [i]'s remaining feature, [Color]. The optimal candidate is therefore [ə]. As in tableau (14), total deletion remains out of reach, however, because under our assumptions GEN cannot simultaneously delete a feature and the root node that contains it. Rather, the root node must be entirely depleted of features before it can delete.

(17) Non-differential dialect deletion of low vowels Step 2

i	*V$_{WEAK}$-GRAD	*[ ]	MAX	*V$_{WEAK}$-CAT
a. → ə		*	*	
b. i	*!			*

At Step 3 (18), the empty root node that represents schwa deletes, thereby satisfying *[ ]. The situation is the same as tableau (15). The derivation then converges at Step 4.

(18) Non-differential dialect deletion of low vowels Step 3

ə	*V$_{WEAK}$-GRAD	*[ ]	MAX	*V$_{WEAK}$-CAT
a. → Ø			*	
b. ə		*		

In differential dialects, the ranking is different. The constraint *V$_{WEAK}$-CAT rather than *V$_{WEAK}$-GRAD dominates *[ ] and MAX, and *V$_{WEAK}$-GRAD is ranked below MAX. As a result of this ranking, the high vowels are subject to deletion because their featural structure can be removed in a single derivational step, thereby satisfying *V$_{WEAK}$-CAT, as shown in tableau (19)

(19) Differential dialect deletion of high vowels Step 1

i	*V$_{WEAK}$-CAT	*[ ]	MAX	*V$_{WEAK}$-GRAD
a. → ə		*	*	
b. i	*!			*

This derivation then continues (20) with deletion of schwa, because *[ ] dominates MAX. The derivation then converges at Step 3.

(20) Differential dialect deletion of high vowels Step 2

ə	*V_{WEAK}-CAT	*[ ]	MAX	*V_{WEAK}-GRAD
a. → Ø			*	
b. ə		*!		

Differential and non-differential dialects are distinguished by their treatment of low vowels. As we saw in (16)-(18), non-differential dialects reduce (and eventually delete) /a/ because of high-ranking *V_{WEAK}-GRAD. In the differential dialects, however, *V_{WEAK}-GRAD is low-ranking, and the reduction of high vowels is a consequence of high-ranking *V_{WEAK}-CAT. But *V_{WEAK}-CAT cannot compel reduction of low vowels: low vowels have two features, [Open] and [Color], that can only be deleted one at a time, but *V_{WEAK}-CAT is satisfied only if both are deleted. The derivation therefore converges at Step 1, as shown in (21).

(21) Differential dialect non-deletion of low vowels Step 1

a	*V_{WEAK}-CAT	*[ ]	MAX	*V_{WEAK}-GRAD
a. → a	*			**
b. i	*		*!	*

HS in general and our assumptions about GEN in particular are essential to this explanation for the immunity of low vowels from deletion in differential dialects. Because GEN can delete only one structural element at a time, it cannot fully deplete /a/ of its features [Open] and [Color] in a single derivational step. In other words, [ə] is not a candidate – it is inaccessible – when the input is /a/. But [ə] is the only vowel that satisfies *V_{WEAK}-CAT, so this constraint cannot cause /a/ to reduce. It does compel reduction of /i/ or /u/, however, because they are just one derivational step away from [ə].

In this way, HS offers a different perspective on phonological mappings of reduction and deletion. Markedness constraints can be thought of as goals, and improvement in performance on a markedness constraint is progress toward the goal that it establishes. If progress toward a goal is possible in a single derivational step, and if faithfulness is low-ranked, then an unfaithful candidate will win, the derivation will not have converged, and another pass through GEN and the grammar will occur. But if progress toward the goal requires multiple steps, there will be no progress at all. This is an important difference between HS and standard OT, because in standard OT the effects of multiple operations in GEN are evaluated simultaneously.

At the beginning of this section, I offered the premise that segments with more structure are less likely to delete than segments with less structure, all else being equal. This premise can be derived from the structure of HS, following the reasoning in the preceding paragraph. We have seen how this premise is instantiated in the distinction between differential and non-differential dialects of Arabic, and I have provided an HS analysis of this distinction. In the next section, we will examine this claim from a broader cross-linguistic perspective.

Deletion of Fuller Segments Implies Deletion of More Reduced Segments

HS, under the assumption that GEN can delete only one structural element in a single derivational step, predicts an implicational hierarchy of susceptibility to deletion. Under the assumptions about the representation of vowels in (10), the implicational hierarchy is the one in (22). Languages that delete /a/ must also delete /i/ and /ə/, and languages that delete /i/ must also delete /ə/. This follows from the fact that /a/ has a proper superset of /i/'s structure, and /i/ has a proper superset of /ə/'s structure. GEN cannot remove more than one element of that structure at a time, so the loss of structure from /a/ changes it into [i] and then [ə] on the way to Ø. Likewise, the loss of structure from /i/ changes it into [ə] on the way to Ø.

(22) Implicational hierarchy of susceptibility to deletion

/a/ → Ø implies

/i/ → Ø implies

/ə/ → Ø

This implicational hierarchy is, of course, the whole point of the distinction between differential and non-differential dialects. Non-differential dialects start at the top of the hierarchy, with both /a/ and /i/ deleting. Differential dialects are located at the middle of the hierarchy: /i/ deletes, but not /a/.

What about /ə/? It is often said that Arabic dialects, other than Maghrebi varieties, do not have underlying /ə/. This is claimed because the dialects either lack surface [ə] entirely or have it only in predictable contexts. In Optimality Theory, however, the standard assumption of *richness of the base* is that there are no language-particular restrictions on underlying representations (Prince & Smolensky, 1993/2004). All phonological generalizations must emerge from the grammar, without assistance from prior restrictions on the inputs to the grammar. A prohibition on /ə/ in the underlying representations of Arabic is exactly the sort of restriction that richness of the base was intended to rule out. It follows, then, that the phonological grammar of Arabic must dispose of any /ə/s in hypothesized underlying representations. The mapping /ə/ → Ø will do exactly that.

The implicational hierarchy in (22) appears to be consistent with the facts of other Semitic languages. The two with which I am most familiar, Akkadian and Tiberian Hebrew, both follow the non-differential pattern, with both non-low and low vowels subject to deletion (Gesenius, 1910; Greenstein, 1984; Huehnergard, 2005). Examples of non-Semitic languages that follow the non-differential pattern are Hopi (Jeanne, 1982), Tonkawa (Hoijer, 1933, 1946), Aguaruna (Payne, 1990), and Macushi Carib (Hawkins, 1950).

Historical developments in the history of Romance clearly followed the differential pattern, with low vowels not yielding to the deletion process that took medial non-low vowels (Hartkemeyer, 1997, 2000). There is also evidence that high vowels were less resistant to deletion than mid vowels (Lief, 2006), a further refinement of the implicational hierarchy in (22).

The Salish language Lushootseed presents a possible counterexample (Gouskova, 2003; Urbanczyk, 1996); Gouskova also mentions Georgian and Estonian.

A final possibility implied by (22) is a differential language where only /ə/ deletes. As I hinted earlier in the discussion of richness of the base, these are languages without any general process of vowel deletion but where schwa has a predictable distribution, from which it follows that the grammar maps /ə/ to Ø in some contexts. Though Maghrebi dialects of Arabic are sometimes described in these terms, the contrast between [ktəb] 'he wrote' and [kətb] 'writing' challenges the claim of complete predictability. A better example is the Salish language Lillooet (St'át'imcets), in which surface [ə] does not occur unless it is needed to satisfy one of the following three requirements (Gouskova, 2003; van Eijk, 1997): (i) there are no vowelless words; (ii) there are no sonorant consonants unless adjacent to a vowel; and (iii) clusters of three consonants are prohibited. In this language, the markedness constraint that [ə] violates, *[ ], dominates MAX, but is itself dominated by the markedness constraints that embody the conditions in (i)-(iii).

In summary, I have shown how the distinction between differential and non-differential dialects, as well as similar distinctions in language typology, follows from the architecture of HS, a minimal assumption about GEN, and current views on the representation of segments. If a segment ς deletes in some context, then all segments with a proper subset of ς's structure must also delete in that context. This follows because deletion of ς proceeds by way of intermediate stages with subset structure, given the assumption that GEN's operations remove one structural element at a time.

We will now turn from the effects of reduction and deletion to the contexts in which they occur, developing further evidence for the HS analysis proposed here.

Every Deletion Context Is Also a Reduction Context

As we saw in the previous sections, deletion of a non-schwa vowel requires one or more reduction steps along the way. In the non-differential dialects, underlying /a/ must reduce to [i] and then [ə] on its way to Ø. In both types of dialects, underlying /i/ and /u/ must first reduce to [ə] on their way to Ø. From this it follows that the contexts in which deletion of non-schwa (hereafter, "full") vowels occurs must be a (possibly improper) subset of the contexts in which reduction of these vowels occurs.

Before proceeding to investigate this prediction, let us first clarify what exactly is being predicted. There are two main predictions, one intralinguistic and the other interlinguistic. The intralinguistic prediction is this: the reduction contexts in some language may be a proper subset of the deletion contexts in that same language. In other words, there may be situations where a full vowel reduces but deletion of [ə] is blocked in some contexts by, say, restrictions on syllable structure. The interlinguistic prediction is this: if in some language full vowels are observed to *delete* in some context X, then full vowels may be observed to *reduce* in the same context in other languages. This prediction follows from ranking permutation: the final deletion step that eliminates [ə] is required only when *[ ] dominates MAX. With the opposite ranking of these constraints, [ə]s derived by reduction will not delete. OT's inherently typological character is responsible for this entailment.

The intralinguistic prediction can be exemplified with antigemination effects (Baković, 2005; McCarthy, 1986). In Syrian Arabic, vowel deletion is blocked between identical consonants, as shown by the second example in (23). The first example shows that in the same context, except that the surrounding consonants are non-identical, the vowel is indeed deleted. Importantly, and consistent with our prediction, the vowel that is not deleted nonetheless reduces to [ə] in Syrian.

(23) Antigemination in Syrian Arabic (Cowell, 1965)

/j-sakkir-u/	jsakkru	'they close'
/j-sabbib-u/	jsabbəbu	'they cause'

I will present an analysis of Syrian Arabic under the assumption that the Obligatory Contour Principle (OCP) blocks syncope between identical consonants (following McCarthy, 1986). Syrian is a differential dialect, so the ranking is the same as (19), except for the addition of the OCP ranked above *[ ]. At Step 1 in (24), the vowel /i/ reduces to [ə], thereby satisfying *V_{WEAK}-CAT. If the surrounding consonants were non-identical, the derived [ə] would go on to delete at Step 2, exactly as it did in tableau (20). But because the OCP dominates *[ ], deletion is blocked at Step 2 (25), and the derivation converges.

(24) Antigemination in Syrian Arabic Step 1

bib	$*V_{WEAK}$-CAT	OCP	*[ ]	MAX	$*V_{WEAK}$-GRAD
a. → bəb			*	*	
b. bib	*!				*

(25) Antigemination in Syrian Arabic Step 2

bəb	$*V_{WEAK}$-CAT	OCP	*[ ]	MAX	$*V_{WEAK}$-GRAD
a. → bəb			*		
b. bb		*!		*	

This example nicely illustrates the intralinguistic prediction about the relationship between reduction and deletion contexts. Deletion of full vowels proceeds by way of a reduction step, so if the deletion step is blocked, as it is in the antigemination cases, the vowel will nonetheless reduce. In other words, the antigemination effect allows us to probe the otherwise invisible reduction step of the HS derivation.

The interlinguistic prediction is a claim about language typology. Because reduction is an unavoidable step along the way to deletion of full vowels, and because the final deletion step is controlled by a different markedness constraint than the reduction step(s), it follows that contexts in which deletion is observed in one language can be contexts in which reduction is observed in another.[6]

Variation among the Arabic dialects often presents excellent opportunities to study language typology (Broselow, 1992; Farwaneh, 1995; Kenstowicz, 1983; McCarthy, 1979), but unfortunately not in this case. The historical development of the dialects almost surely involved a reduction stage before the vowels were deleted entirely, but the shift from reduction to deletion was carried through almost universally in the dialects, except for occasional vestiges of reduction like the antigemination effect discussed above. Reduction and deletion of the reduced vowel have been historically “telescoped” (Wang, 1968), so that all that remains visible is deletion.

We can, however, find the necessary typological evidence in languages other than Arabic. One common context for both reduction and deletion is post-tonic – that is, after the stressed syllable. The post-tonic region of the word is often associated with a greater degree of vowel reduction than the pre-tonic region. This distinction is the focus of Maiden (1995) and Walker (2016); also see Crosswhite (2004) and Hyman (2002, pp. 23-24). Yiddish is a good example (N. G. Jacobs, 2005, p. 103). The data in (26) show that post-tonic reduction of full vowels to [ə] is observed both in alternations and in assimilation of loanwords. Vowels in pre-tonic position do not reduce, however.

(26) Post-tonic Reduction in Standard Yiddish

a. Post-tonic reduction alternations

	Singular	Plural	
/talmid/	ˈtalməd	talˈmidəm	‘pupil’
/ganov/	ˈganəf	gaˈnovəm	‘thief’
/ʃabos/	ˈʃabəs	ʃaˈbosəm	‘Sabbath’

b. Post-tonic reduction in loanwords (variably)

ˈpejdə	‘wages (< *pay day*)’
ʃiˈkago ~ ʃiˈkagə	‘Chicago’
ˈgumi ~ ˈgumə	‘rubber (< German *Gummi*)’,
ˈblotə	‘mud (< Polish *błoto*)’

c. No reduction pre-tonically

niˈgunəm	‘melodies’
ekˈran	‘screen’
uˈkraynə	‘Ukraine’

Post-tonic reduction can also be found in some southern Italian dialects (Maiden, 1995, pp. 116-117). In Southern Lucanian, for instance, the pre-tonic vowel system consists of [a], [u], and [ə], while the post-tonic system is just [ə] (see (27)).

(27) Southern Lucanian vowel reduction (Lausberg, 1939)

a. Post-tonic vowel system

ˈfikətə	‘liver’
ˈfumə	‘smokes’
ˈpreβətə	‘priest’
ˈpartənə	‘they leave’

b. Pre-tonic vowel system

naˈta	‘to swim’
məsuˈra	‘to measure’
suɲˈɲa	‘to dream’
βəˈde	‘to see’

The post-tonic region of the word is also a context for vowel deletion. In the Modern South Arabian language Jibbāli (Hayward, Hayward, & Al-Tabūki, 1988), post-tonic vowels are highly reduced or deleted entirely, leading to alternations like those in (28). The fleeting superscripted schwa optionally breaks up clusters that would otherwise be problematic because the second consonant is [r] or a guttural (Hayward et al., 1988, p. 243). Post-tonic syncope is also found in Late Latin/early Romance (for recent discussion, see H. Jacobs (2004), Mester (1994), and Wheeler (2007).)

(28) Post-tonic deletion in Jibbāli

	‘he’	‘she’	
/feðer/	ˈfeðr ~ ˈfeð^{ə}r	feðeˈrɔt	‘shivered’
/ðeker/	ˈðekr ~ ˈðek^{ə}r	ðekeˈrɔt	‘remembered’
/s^{ʔ}edef/	ˈs^{ʔ}edf	s^{ʔ}edeˈfɔt	‘was dented’

As in Jibbāli, cluster conditions can limit the effect of post-tonic syncope. For example, the reflex of Classical Latin [ˈjuweneːs] ‘youths’ in Catalan is [ˈʤovəns] because conditions on clusters and syllabification rule out alternatives like *[ˈʤovnəs] and *[ˈʤovns] (Wheeler, 2007).

An even more extreme case of post-tonic deletion – deletion of *all* post-tonic segments, both vowels and consonants – is characteristic of certain quasi-morphological truncation processes. Examples include central Italian vocatives (29), English *totesing* (30), and truncation in Coeur d’Alene/Montana Salish (31).

(29) Central Italian vocatives (Maiden, 1995, p. 118)

[avvoˈkatu]	[avvoˈka]	‘lawyer!’
[miˈkele]	[miˈke]	‘Michele!’
[doˈmeniko]	[doˈme]	‘Domenico!’

(30) English *totesing* (Spradlin, 2016)

tótally	tótes
atrócious	atró[ʃ]
demócracy	demóc
inapprópriate	inappróp
clarificátion	clarificá[ʃ]

(31) Truncation in Coeur d’Alene (Doak, 1990; Thomason & Thomason, 2004)

stˀʃástq	stˀʃá	‘huckleberries’
sʦˀɛwˀɛnínɛʔ	sʦˀɛwˀɛní	‘giant’
stˀmˀáltmʃ	stˀmˀá	‘buffalo’
tkʷarʷarέqɛʔst	tkʷarʷarέ	‘orange’

Tableaux (5)-(6) showed how the reduction-deletion chain can affect consonants as well as vowels. In these three examples, weakness in the post-tonic region causes reduction and deletion of both vowels and consonants. Post-tonic consonant reduction without deletion can also be observed, as our theory would predict. For example, in the Liverpool dialect of English (known as Scouse), coda /t/ lenites to [h] or [ʦ] depending on context (see (32)). In a stressed prepausal syllable, lenition to [ʦ] is the only option. But in an unstressed prepausal syllable /t/ optionally reduces even further, debuccalizing to [h]. This example shows that reduction of consonants can be stress-conditioned in much the same way that reduction of vowels is, establishing a parallel between vowel and consonant reduction. Indeed, one might suppose that the reduced consonants [h] and [ʔ] are to full consonants what [ə] is to full vowels: the segment that remains when most or all featural structure is absent.

(32) Scouse prepausal /t/ allophones (K. Watson, 2002)

a. [h] ~ [ʦ] in unstressed codas

clíma[h~ ʦ]
pílo[h~ ʦ]
búdge[h~ ʦ]
pérmi[h~ ʦ] (noun)

b. [ʦ] but not [h] in stressed codas

uppercú[ʦ]
acrobá[ʦ]
permí[ʦ] (verb)

In summary, we have seen evidence for two consequences of the HS approach to vowel deletion developed in this paper, in which reduction is a necessary step along the way toward deletion of full vowels. The antigemination effect in Syrian Arabic establishes this linkage within a single language: when deletion is blocked under specific conditions, reduction nevertheless occurs. The evidence of weakening processes in the post-tonic domain confirms this linkage cross-linguistically: the post-tonic environment triggers segmental reduction in some languages and segmental deletion in others. The reduction/deletion connection is confirmed.

We turn now from the contexts of reduction and deletion to the consequences of this theory for segmental representation.

Consequence: Segments Have Internal Structure

This analysis of vowel reduction and deletion processes has relied on the assumption that vowels are collections of objects, and reduction is removal of one of those objects. Distinctive features are objects, with a relationship to segments that is analogous to the relationship of atoms to molecules.

This "molecular" view of segmental representation might seem hardly worth remarking upon, since it has been practically a truism of phonological theory since the advent of autosegmental phonology (Goldsmith, 1976). Still, there are reasons not to take it for granted. After all, the original theories of distinctive features (Chomsky & Halle, 1968; Jakobson, Fant, & Halle, 1952) assigned to features a purely classificatory role: they are attributes of segments rather than the objects out of which segments are made. The IDENT constraints of Correspondence Theory (McCarthy & Prince, 1995, 1999) continue that tradition. Lately, an emergentist theory of distinctive features (Mielke, 2008) has dealt exclusively with their classificatory function. So, what might seem to go without saying actually needs to be said and supported with evidence.

To that end, I will review some of the evidence that Arabic offers for features as objects of phonological representation rather than mere attributes of segments. The evidence involves situations where features are alienable properties of segments, capable of moving from one segment to another. To be alienable properties, features must be objects that can exist apart from the segment that originally bore them. Attributes (that is, purely classificatory features) are inalienable properties, and hence cannot be transferred from one segment to the next. To cite an analogy from my previous administrative position as dean of the graduate school, there is a difference between a diploma (an object) and a degree (an attribute). I can sell or throw away my PhD diploma, but my PhD degree is an inalienable quality.

Segmental coalescence combines the features of two input segments into a single output segment. Vowel-glide coalescence in Arabic, exemplified in (33), combines the Color features of the glide with a compromise on the height features of the vowel and glide, changing /aj/ into [e:] and /aw/ into [o:]. This is a thorough rearrangement of the feature-objects that make up the two input segments, with only the weight of the input segments (their moras) remaining unchanged.

(33) Vowel-glide coalescence in Tripoli, Lebanon (el-Hajjé, 1954; McCarus, 1955)

/bajt/	be:t	bajti	'(my) house'
	be:tak		'your house'
/lawn/	lo:n	lawnu	'(his) color'

A similar phenomenon has also been described for Classical Arabic (Owens, 2009, pp. 210-211; Versteegh, 2005, p. II:233; Wright, 1971, pp. I:71, I:84). In the passive of hollow verbs, there is coalescence of the medial vowel-glide-vowel sequence into a single long vowel: /quwila/ → [qi:la] 'it was said'. Though written as [i:], this vowel is described as *al-'išmām* 'the scent' of *kasra* (the Arabic word for the vowel [i]), probably the front rounded vowel [y], hence [qy:la]. If indeed this vowel was high front rounded [y], then it is combining color features of both /uw/ and /i/, much as the coalescence process in (33) combines the height features of the original segments. This reshuffling of features from two distinct segments to create a new one is further evidence that features are entities rather than mere categories.

Apparent assimilation to a deleted segment can also be seen as evidence that features are alienable from the segments that originally bore them. In Bedouin Arabic (34), the color of underlying /i/ remains on a preceding velar even though the /i/ deletes. In Cairene Arabic (35), the color of underlying /u/ remains as labialization of the preceding consonant even when the /u/ has been deleted. For a feature to be transferred from one segment to another, remaining behind as a kind of phantom limb even after the segment that bore it has been deleted, it must be an alienable property of the original segment, rather than an intrinsic quality of it.

(34) Palatalization in Bedouin Arabic (Al-Mozainy, 1981, pp. 49f., 73ff.)

/ħaːkim-iːn/	ħaːkʲmiːn	'ruling (m. pl.)'
/kitib-t/	kʲtibt	'you (m. sg.) were written'

(35) Labialization in Cairene Arabic (Mitchell, 1956, p. 114)

/ʕandi ħuma:r/	ʕandi ħʷma:r	'I have a donkey'

Classical Arabic had a similar phenomenon to Cairene, for which the term *'išmām* was also used. When a word ending in the nominative suffix /u/ occurred in pause, where deletion of final short vowels is required, "in place of a final *u* the lips might be inaudibly rounded after the preceding consonant (*'išmām*)" (Hoberman, 2005, p. III:566). Owens (2009, pp. 22, 210) proposes that pausal /u/ is devoiced rather than deleted (e.g., [alkita:b-u̥], though that is difficult to reconcile with Sibawaih's report that a blind person cannot detect it – that is, it is truly inaudible.

Finally, the most striking evidence in Arabic that features are independent entities comes from a secret language. One major source of evidence for the independence of tone from segments came from transpositional secret languages (Bagemihl, 1988; Coupez, 1969; Hombert, 1973, 1986). In Bakwiri (36), the L(ow)-H(igh) word [mɔ̀kɔ́] remains L-H even as the segments of the two syllables are swapped. Likewise, the H-L word [kwélì] remains H-L. Evidence like this, which is abundant in Bantu languages, shows very clearly that tones are independent entities rather than attributes of particular segments.

(36) Bakwiri language game (Hombert, 1986, p. 178)

Normal	Game	
mɔ̀kɔ́	kɔ̀mɔ́	'one person'
kwélì	líkwè	'death'

A similar point can be made about vowel length, as in the Sanga language game exemplified in (37). When the segments are transposed, both tone and vowel length are left behind. It is now a standard assumption of phonological theory that tone and segmental quantity are represented on separate tiers from the segments themselves, and thus they are clearly not inalienable properties of segments.

(37) Sanga language game (Coupez, 1969, p. 33)[7]

Normal	Game
múkwèː̀tù	mútùː̀kwè
báː́kólwèː́	báː́lwékòː́

Evidence of this sort for non-tonal features is not terribly common, but there is a striking example in Moroccan Arabic. The feature that remains behind even as segments are transposed is pharyngealization (also known as emphasis or *tafxīm*). In the *sin* secret language of Oujda, a word of the form C_1… is transformed into *s*…*sin*C_1*a*, as shown in by the examples in (38a). When the initial consonant is pharyngealized or geminated (38b), however, the pharyngealization and gemination remain behind and are transferred to the [s] that is supplied by the language game. This treatment of gemination is unsurprising in view of how vowel length is behaving in the Sanga secret language (37). But the treatment of pharyngealization provides compelling evidence that is an alienable entity rather than an inalienable property of the segment /dˤ/.[8]

(38) Moroccan *sin* language (Youssi, 1976, 1977)

a.	Normal	Secret	
	ktab	stabsinka	‘book’
	qallu	sallusinqa	‘he spoke to him’
	waʃ	saʃsinwa	question particle
	mnin	sninsinma	‘whence’
b.	dˤar	sˤarsinda	‘house’
	dˤdˤar	sˤsˤarsinda	‘the house’

In summary, this chapter’s central thesis – that deletion of whole segments is the end result of a sequence of deletions affecting individual pieces of segmental structure – entails that segments have internal structural elements that a deletion operation in GEN can address individually. We have seen independent evidence for that entailment from segmental coalescence, phantom-limb effects, and a secret language. Distinctive features are entities rather than attributes. Hence, they can be deleted, preserved, or moved independently of the segments that originally bore them. This view of what features are is consistent over the range of phenomena discussed not only in this section but also throughout this chapter.

Conclusion

Harmonic Serialism offers a new perspective on familiar phonological processes, deletion among them. The possibility of decomposing a seemingly unitary process into a sequence of smaller steps – and doing so in a principled way, under an explicit theory of GEN and CON – may have interesting empirical consequences. As we have seen in this chapter, the empirical consequences of decomposing deletion in this way may very well be correct.

This project raises as many questions as it answers, if not more. One class of questions involves the general theory of GEN and CON in which the deletion operation and constraints like *V_{WEAK}-GRAD are embedded. Ideally, GEN and CON would be more than just lists of operations and constraints, respectively. It would be preferable if the existence of a single-element deletion operation and the non-existence of multi-element deletion operations followed from a general theory of operations. Similarly, we would like to understand better how this more granular view of operations affects the kinds of constraints that CON requires, just as *V_{WEAK}-GRAD makes sense in a theory where segments delete by graduate attrition.

The proposal that vowel deletion happens gradually leads to an obvious vice-versa question: is epenthesis also gradual? Is [ə] the first and sometimes the last step in epenthesis, with epenthetic [i] or [a] derived from it? There is some reason to think that this is correct. Farwaneh (1995, p. 126ff.) observes that the two varieties of Arabic with epenthetic [a] only ever epenthesize it into an open syllable:[9] /kalb-kum/ → [kalbakum] 'your (pl.) dog'; /bank-na/ → [bankana] 'our bank'. Moreover, they are both differential dialects. In other words, epenthetic [a] occurs in a context where epenthetic [i] would violate the same markedness constraint that is responsible for deletion of /i/. These observations about the contextual and typological limitations on epenthetic [a] hint at a derivation in which epenthetic [i] is an intermediate step toward epenthetic [a]. This is what we would expect if derivational epenthesis of [a] is derivational deletion of /a/, reversed.

Finally, what can be said about the kind of wholesale segmental deletion that can occur in template-mapping morphology? We have already seen hints of this in the discussion of post-stress truncation processes in (28)-(31), but what of processes like the formation of the templatic hypocoristics in (39)? In this pattern, root consonants are mapped to a C*a*CC*u:*C template. The template acts as the licensor, and segments that are unlicensed because they are not associated with the template are deleted. Since the features making up the unlicensed segments are also unlicensed, gradual attrition, deleting the unlicensed features one at a time, is certainly a possibility.[10]

(39) Colloquial Arabic hypocoristics (Davis & Zawaydeh, 2001, p. 515)

Name	Hypocoristic	Root
muħammed	ħammu:d	√ħmd
ʔamʒad	maʒʒu:d	√mʒd
ʔibitisa:m	bassu:m	√bsm
marja:m	marju:m	√mrjm

These, then, are some of the questions to which this exploration of deletion and reduction processes in OT has led us.

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[2] Omitted from (1)-(3) is the candidate [fiʕal]. It is ruled out by the undominated constraint I-CONTIG (McCarthy & Prince, 1995, 1999), which militates against internal epenthesis.

[3] This example is based on McCarthy (2008).

[4] Though see Kurisu (2012) for a different view, and Hall, Jurgec and Kawahara (to appear) for a rejoinder to Kurisu.

[5] An anonymous reviewer notes that English instantiates this prediction: vowels reduce in more contexts than they delete. See for example Zwicky (1972).

[6] An anonymous reviewer asks about cases where the antigemination effect does not lead to reduction when deletion is blocked. An example is Afar (Bliese, 1981; McCarthy, 1986): /digib-é/ → [digbé] 'she/I married' vs. /danan-é/ → [danané], *[danəné] 'I/he was hurt'. It may be that the OCP effect in this case is not a prohibition on adjacent identical segments, but rather tier-adjacent identical Place nodes. Reduction of a full vowel between identical consonants renders the consonants Place nodes tier-adjacent.

[7] Coupez does not gloss individual words, only entire sentences rendered in their language game form.

[8] See also Broselow's (1979) proposal that pharyngealization is a property of syllables rather than segments in Cairene Arabic.

[9] The dialects with epenthetic [a] are Sudanese (Hamid, 1984; Trimingham & Gairdner, 1946) and Saudi (Abu-Mansour, 1987, 1991).

[10] For an approach to reduplicative template mapping in HS, see McCarthy, Kimper & Mullin (2012).