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The gradual path to cluster simplification

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When a medial consonant cluster is simplified by deletion or place assimilation, the first consonant is affected, but never the second one: /patka/ becomes [paka] and not *[pata]; /panpa/ becomes [pampa] and not [panta]. This article accounts for that observation within a derivational version of Optimality Theory called Harmonic Serialism. In Harmonic Serialism, the final output is reached by a series of derivational steps that gradually improve harmony. If there is no gradual, harmonically improving path from a given underlying representation to a given surface representation, this mapping is impossible in Harmonic Serialism, even if it would be allowed in classic Optimality Theory. In cluster simplification, deletion or Place assimilation is the second step in a derivation that begins with deleting Place features, and deleting Place features improves harmony only in coda position.

1 Introduction

Classic Optimality Theory is a parallel theory of grammar (Prince & Smolensky 1993). In other words, it evaluates fully formed output candidates that may show the effects of many different processes simultaneously. The winning candidate is simply the most harmonic member of the candidate set, according to some language-particular constraint hierarchy.

There is a version of OT called Harmonic Serialism (HS). HS is a serial or derivational theory of grammar, but, unlike more familiar derivational theories, it is based on candidate evaluation by ranked constraints rather than rules. HS imposes a requirement of GRADUALNESS, which restricts how much a candidate can differ from the input. This more limited

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candidate set is evaluated, its most harmonic member is chosen as output, and that output becomes input for another pass through the grammar. Thus, HS takes a gradual path to the ultimate output of the grammar, whereas classic OT proceeds immediately to the ultimate output.

A consequence of gradualness is that there are input–output mappings that classic OT allows but HS does not, all else being equal. In the simplest case, a classic OT grammar maps A to C, but the differences between A and C are sufficient to require an intermediate step B in the HS analysis. That is, the flat classic OT derivation is A → C, but the serial HS derivation has to be A → B → C because of gradualness. For A → B → C to be a possible HS derivation, B must be more harmonic than the faithful candidate A and less harmonic than C, according to the constraint hierarchy. If no such B exists – for instance, because there is no markedness constraint which favours B over A – then it will not be possible to get from A to C in HS, even though this mapping is possible in classic OT. C is therefore inaccessible from A.

In this article, I argue that this property of HS is an asset. The evidence comes primarily from an observation known as the CODA/ONSET ASYMMETRY. In many languages, consonant clusters simplify by deleting the first consonant, but never the second one (Wilson 2000, 2001, Steriade, forthcoming): /patka/ → [paka], not [pata]. In many languages, clusters assimilate by changing the first consonant to match the second one, but not the other way around (Webb 1982, Ohala 1990, Mohanan 1993, Jun 1995, 2004, Steriade 2001): /panpa/ → [pampa], not *[panta]. In short, the would-be coda is often targeted for deletion or assimilation, but the would-be onset never is.

The HS explanation for the coda/onset asymmetry has two components: deletion or assimilation requires two steps, the first of which is loss of the Place node; and loss of the Place node is harmonically improving in codas but not onsets. I will show that both aspects of the explanation have a principled basis, are supported by independent evidence and are precedented in the literature of both rule-based phonology and OT. I will also show that the HS explanation avoids the problems of other extant approaches to the coda/onset asymmetry.

The coda/onset asymmetry is one instance of a range of typological observations that have been known as 'too many repairs' (TMR) or 'too many solutions' problems ever since Lombardi (2001) and Pater (1999) first discovered them.[1] In a TMR problem, the observed ways of satisfying a markedness constraint by an unfaithful mapping are a proper subset of the ways that are predicted by free permutation of faithfulness constraints. Thus, the coda/onset asymmetry is a TMR problem because the markedness constraint(s) usually deemed to be responsible for cluster simplification could equally well be satisfied by altering the first consonant

[1] The names 'too many repairs' and 'too many solutions' are well entrenched but unfortunate, since there is nothing in OT itself that answers to a 'repair' or a 'solution'.

or the second one, but only alterations in the first consonant are ever observed.

The full range of TMR problems is too big and ill-defined to be addressed in just this article, but in other work I have argued that HS can solve other TMR problems besides the coda/onset asymmetry. Blumenfeld (2006) has identified stress–syncope interaction as a TMR problem, and in McCarthy (forthcoming) I develop an HS analysis of the typology of stress–syncope interactions. In McCarthy (2007b), I discuss several TMR problems and their solutions in HS: the inability of constraints on word- and syllable-final consonants to conspire to delete word-final sequences of non-conforming segments; the impossibility of double (/apekto/ → [paketo]) or long-distance (/art/ → [tar]) metathesis; the limitation of autosegmental flop processes to situations where assimilation would also be possible; and the impossibility of long-distance feature spreading to satisfy a highly local markedness constraint. From all of this, it would appear that HS has a significant contribution to make toward understanding the differences between licit and illicit input–output mappings in phonology and perhaps elsewhere.

2 Harmonic Serialism

2.1 Overview

Prince & Smolensky (1993: 94–95) mention HS as a possible variant implementation of OT. HS differs from classic OT in two respects: GEN, and the GEN → EVAL → GEN … loop.

In OT, the GEN component creates candidate output forms from an input. Classic OT's GEN produces a highly diverse candidate set; a candidate can differ from the input in many different ways at once. HS's GEN produces a restricted candidate set; there is no more than one difference between any candidate and the latest input. For instance, the candidate set for input /pat/ would include [pat], [pa.ti] and [pa.tʃi] in classic OT, but [pa.tʃi] would be absent from the HS candidate set.[2] This property of HS is called GRADUALNESS. It will be defined in the next section.

In OT, the EVAL component applies a language-particular constraint hierarchy to select the most harmonic member of the candidate set. EVAL works exactly the same in the two theories; only the candidate set that it evaluates differs.

In classic OT, the output of EVAL is also the ultimate output of the grammar. In HS, however, the output of EVAL is fed back into GEN as a new input for another pass through GEN and EVAL. This GEN → EVAL → GEN … loop terminates when there is CONVERGENCE: the candidate selected by EVAL is identical with the most recent input to GEN. Once that has happened, no further changes are possible, and we have the ultimate output of the grammar. For example, if a language has a constraint hierarchy

[2] The period/full stop indicates a syllable boundary.

that favours epenthesis of [i] after codas and palatalisation of [t] before [i], then the output of /pat/'s first pass through GEN and EVAL will be [pa.ti], and the output of [pa.ti]'s pass through GEN and EVAL will be [pa.ʧi]. Submitting [pa.ʧi] to GEN and EVAL yields [pa.ʧi] as the output once again – convergence. We can write this series of steps compactly as <pat, pa.ti, pa.ʧi>.

Because EVAL applies repeatedly, each step in the derivation <pat, pa.ti, pa.ʧi> must better satisfy the constraint hierarchy than its predecessor. This property of HS is called HARMONIC IMPROVEMENT. Harmonic improvement is always determined relative to a particular constraint hierarchy that is invariant across all iterations of the GEN → EVAL → GEN … loop. As long as all constraints evaluate outputs (markedness) or require input–output identity (faithfulness), convergence in a finite number of loops is guaranteed. In other words, every underlying representation has finite potential for harmonic improvement (Moreton 2000, 2004).

To show harmonic improvement in an HS derivation, we require a device similar to classic OT's winner-loser tableau. An example of a HARMONIC IMPROVEMENT TABLEAU appears in (1). It illustrates the rankings necessary for harmonic improvement in the HS derivation <pat, pa.ti, pa.ʧi>. (For the definition of CODACOND, see (6).)

(1) *Harmonic improvement tableau*

/pat/	CODACOND	*ti	DEP	IDENT[ant]
a. pat *is less harmonic than*	*!			
b. pa.ti *is less harmonic than*		*!	*	
c. pa.ʧi			*	*

Tableau (1) illustrates a couple of conventions that will be followed throughout this article. The exclamation point is used to signal a constraint violation whose removal at the next step in the derivation improves harmony. Harmonic improvement requires that any violation marks added at the next step be ranked lower than the violation that is removed. I also follow the practice of showing faithfulness violations relative to the original underlying representation, not to the input of the latest pass through GEN. This assumption is not crucial in this article, but it is required for the proper application of HS to phonological opacity (McCarthy 2007a).

(1) certifies that <pat, pa.ti, pa.ʧi> is harmonically improving under the given constraint hierarchy. The form [pa.ti] in (1b) improves over the harmony of [pat] in (1a) because [pa.ti] eliminates [pat]'s CODACOND violation without adding violations of any constraints ranked higher than CODACOND (there are none). Likewise, [pa.ʧi] in (1c) improves over the

harmony of [pa.ti] in (1b) because [pa.ʧi] eliminates [pa.ti]'s violation of *ti without adding violations of any constraints ranked higher than *ti.

Harmonic improvement over the course of a derivation is also important in the theory of Harmonic Phonology, which links rule application to harmonic improvement in the sense of greater conformity with phonotactic requirements (Goldsmith 1990: 319ff, 335–336, 1993a). On the other hand, harmonic improvement over the course of a derivation is not meaningful in another serial approach to optimality, stratal OT (Rubach 1997, Kiparsky 2000, Ito & Mester 2003 and many others). In stratal OT, a different grammar is used on each pass through GEN and EVAL, and grammars differ in what they regard as harmonic improvement. In contrast, HS uses the same grammar on each pass through GEN and EVAL, so harmonic improvement is always determined by the same grammar.

Each step in an HS derivation is also LOCALLY OPTIMAL. This simply means that it is optimal within HS's restricted candidate set for that derivational step. If, say, CODACOND and MAX dominate DEP, then [pa.ti] is locally optimal in comparison with a candidate set that includes faithful [pat] and [pa], with deletion. Even though [pa.ti] is locally optimal, it is not the ultimate output of the grammar, if further harmonic improvement can be achieved by palatalising [t] on the next pass through the GEN → EVAL → GEN … loop.

Harmonic improvement and local optimality are intrinsic to the HS architecture, since they are inherent properties OT's EVAL component, which is exactly the same in HS and classic OT. But gradualness is a restriction that is unique to HS's GEN. The next section discusses the details of this restriction.

For further discussion and applications of Harmonic Serialism, see McCarthy (2000, 2002b: 159–163, 2007a, b, forthcoming).

2.2 Defining gradualness

The origin of HS's gradualness requirement can be found in Prince & Smolensky's (1993: 94–95) original sketch of this model: in GEN, 'some general procedure (Do-α) is allowed to make a certain single modification to the input, producing the candidate set of all possible outcomes of such modification'. The reason for considering such a possibility even at the very beginning of OT is that it recalls certain restrictive theories of phonological (and syntactic) rules.

Chomsky & Halle (1968) formalised phonological processes as unrestricted rewrite rules, but they entertained the possibility of limiting phonology to rules that can alter only one segment at a time (1968: 399). Later work pursued this idea further, limiting rules to single operations on autosegmental association lines (Goldsmith 1976), feature-geometric nodes (Clements 1985) or metrical grid positions (Prince 1983). Archangeli & Pulleyblank (1994) proposed a parametric rule system with a limited vocabulary of elementary phonological operations, insertion and deletion of phonological elements and insertion and deletion of association lines.

Almost from the beginning, syntactic theory has also recognised a set of basic operations, as in Chomsky's (1965: 147) definition of a grammatical transformation: 'a Boolean condition on Analyzability and a sequence of elementary transformations drawn from a base set including substitutions, deletions, and adjunctions'.

HS's gradualness requirement takes a similar approach to OT's GEN component. Very informally, gradualness limits GEN to doing one thing at a time, like Archangeli & Pulleyblank's parametric rules. Getting from /pat/ to [patʃi] therefore requires at least two steps, both of which must be harmonically improving to make it through the GEN → EVAL → GEN … loop.

There are many possible ways of formalising this basic intuition, and further study of more diverse phenomena may very well render current ideas obsolete. Nonetheless, an explicit hypothesis is necessary before we can do any sort of serious analysis in HS. One approach is to establish a connection between the operations in GEN and the faithfulness constraints (McCarthy 2007a: 61–62, 77–79). Certain elementary operations in GEN, such as insertion or deletion of a phonological element, are directly linked to violations of faithfulness constraints, such as MAX and DEP. I will use the term UNFAITHFUL OPERATIONS to refer to them. Other operations, including most of the prosodic parsing apparatus, have no faithfulness consequences. Gradualness limits the use of unfaithful operations in generating candidates.

(2) *Gradualness*

If β is a member of the set GEN(α), then no more than one unfaithful operation is required to transform α into β.

This definition places no limit on the number of faithful operations required in the $\alpha \rightarrow \beta$ mapping. It also places no limit on the number of faithfulness constraints that β violates in comparison with α. A single unfaithful operation can yield violations of several faithfulness constraints – for instance, when both a general and a positional faithfulness constraint are applicable to the same segment.

Because gradualness is defined in terms of faithfulness, the details of faithfulness theory are important in determining the limits of a candidate set. In this article, the treatment of distinctive features in faithfulness theory is crucial.

For over three decades, phonological theory has recognised two views of distinctive features, features as ATTRIBUTES and features as ENTITIES. This difference is reflected in how features are treated by the correspondence theory of faithfulness (McCarthy & Prince 1995, 1999). If features are thought of as attributes of segments, as in Chomsky & Halle (1968), then IDENT[feature] constraints are the appropriate means of expressing faithfulness to them. In autosegmental phonology (Goldsmith 1976), distinctive features are regarded as independent entities. In this view, Max[feature] and Dep[feature] constraints are the appropriate means of expressing faithfulness.

One of the most important differences between the Ident[feature] and Max[feature] theories arises when segments delete (Lombardi 2001). For instance, the mapping /patka/ → [pa.ka] obeys Ident[Place] and violates Max[Place]. This mapping obeys Ident[Place] because, according to the definition in (3), an input segment that has no output correspondent vacuously satisfies Ident[Place].

(3) Ident[Place]

Let *input segments* = $i_1 i_2 i_3 \ldots i_m$ and *output segments* = $o_1 o_2 o_3 \ldots o_n$.
Assign one violation mark for every pair (i_x, o_y), where
i_x is in correspondence with o_y, and
i_x and o_y have different specifications for Place.

In contrast, the /patka/ → [pa.ka] mapping does violate Max[Place], as defined in (4), because an input token of the Place feature [coronal] has no output correspondent.

(4) Max[Place]

Let *input Place tier* = $p_1 p_2 p_3 \ldots p_m$ and *output Place tier* = $P_1 P_2 P_3 \ldots P_n$.
Assign one violation mark for every p_x that has no correspondent P_y.

These two views of featural faithfulness have various empirical consequences that have been explored in earlier work (e.g. Itô *et al.* 1995, Lamontagne & Rice 1995, Causley 1997, Lombardi 1998, 2001, Zoll 1998, Davis & Shin 1999, Gnanadesikan 2004). For present purposes, the interesting thing about them is how they intersect with the definition of gradualness in (2).

(i) If Ident[Place] is assumed, then deletion of a consonant is a single unfaithful operation, since Ident[Place] is not violated when a consonant deletes. In that case, HS's Gen, when given the input /patka/, can offer [pa.ka] as one of the output candidates. Hence, deletion of a consonant can be accomplished in a single step of a properly gradual HS derivation: <pat.ka, pa.ka>.

(ii) If Max[Place] is assumed, then deletion of a consonant will require at least two unfaithful operations, one to delete Place and one (or more) to delete the rest of the consonant. In that case, HS's Gen, when given the input /patka/, *cannot* offer [pa.ka] as one of the output candidates. The best it can do is offer [paH.ka], where [H] denotes whatever is left when /t/'s Place feature has been taken away. Hence deletion of a consonant requires two steps of a properly gradual HS derivation: <pat.ka, paH.ka, pa.ka>.

In short, the Ident[Place] regime treats consonant deletion as a single operation, whereas the Max[Place] regime treats it as gradual attrition.

Similar reasoning applies to Place assimilation. Changing /m/ to [ŋ] incurs a single violation of IDENT[Place], so it can be accomplished in a single step of an HS derivation: <pam.ka, paŋ.ka>. But with MAX[Place], assimilation requires two unfaithful operations. The first violates MAX[Place], changing /pamka/ into [paN.ka], where [N] denotes whatever is left when /m/'s Place feature has been taken away.[3] The second operation violates the faithfulness constraint NOLINK[Place], as defined in (5), because it spreads Place from [k] to [N]. The properly gradual HS derivation is therefore <pam.ka, paN.ka, paŋ.ka>.

(5) 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 Place 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.

(The details of this definition are not important here, but they are provided for completeness. They say that NOLINK is violated when elements that are present but unlinked in underlying representation become linked in the output.)

This view of Place assimilation recalls a theory of assimilation that was well established in the pre-OT literature (Poser 1982, Mascaró 1987, Cho 1990, Kiparsky 1993).[4] A mapping like /pamka/ → [paŋ.ka] is a case of feature-changing assimilation, and it was proposed that all apparent feature-changing assimilation rules should be analysed as a combination of a feature-deleting neutralisation rule and a feature-filling assimilation rule, applied in that order. With HS and the assumption that neutralisation violates MAX[Place], the gradualness requirement (2) entails this same decomposition of feature-changing assimilation into neutralisation plus spreading.

In this article, I assume that MAX[Place] is the right faithfulness constraint. In consequence, consonant deletion or assimilation requires two derivational steps, with a Placeless consonant as the intermediate step: [paH.ka], [paN.ka]. I will show how this accounts for the coda/onset asymmetry: the intermediate steps required for onsets to delete or undergo assimilation – that is, [pat.Ha] and [pam.Ha] – do not improve performance on CODACOND.

[3] The placeless nasal [N] is the *anusvāra* or nasal glide of Sanskrit (Whitney 1889: 24–25), Japanese (Vance 1987: 35) and Caribbean Spanish (Trigo 1988). There is no oral closure during the production of this sound, but because the soft palate is lowered, the point of maximal constriction is in the dorsal region. For this reason, it is often transcribed as [ŋ].

[4] For discussion of this topic in the OT literature, see Inkelas (1995) and Reiss (2003).

3 Analysis

3.1 Harmonic improvement in coda deletion

We know from §2.2 that the HS derivation <pat.ka, paH.ka, pa.ka> meets the gradualness requirement, but it must also be harmonically improving in any language that simplifies medial clusters by deleting the first consonant. Specifically, if the intermediate step [paH.ka] is not more harmonic than [pat.ka] and less harmonic than [pa.ka], then this derivational path will be impossible in HS. The goal of this section is to establish the ranking conditions under which this sequence is indeed harmonically improving.

Cluster simplification is usually attributed to CodaCond, which is defined in (6). This is an onset-licensing formulation of CodaCond, along the same general lines as Goldsmith (1990: 123–128). Place is licensed by association with an onset consonant; a Place node that is so licensed can also be associated with a preceding coda without violating CodaCond (cf. Itô 1989 for a somewhat different formulation of this constraint).

(6) CodaCond

Assign one violation mark for every token of Place that is not associated with a segment in the syllable onset.

Whereas [pat.ka] violates CodaCond because of [t]'s [coronal] specification, [paH.ka] does not, since [H] has no Place features. Therefore, a necessary condition for harmonic improvement in <pat.ka, paH.ka> is for CodaCond to dominate Max[Place]. This ranking is shown in the harmonic improvement tableau (7).

(7) *Harmonic improvement in* <pat.ka, paH.ka>

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

For <pat.ka, paH.ka, pa.ka> to be a possible derivation, the step from [paH.ka] to [pa.ka] must also improve harmony. It does so if the markedness constraint HavePlace in (8) dominates the faithfulness constraint violated by deleting [H] – i.e. Max.

(8) HavePlace (after Padgett 1995, Parker 2001, Smith 2002)

Assign one violation mark for every segment that has no Place specification.

All of the constraint rankings necessary for harmonic improvement in <pat.ka, paH.ka, pa.ka> are summarised in (9). If a language has this constraint hierarchy and no other rankings undermine it, then /patka/ will map to [pa.ka] by way of [paH.ka].

(9) *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			*	*

Tableau (9) shows that getting from [pat.ka] to [paH.ka] in a harmonically improving fashion requires that CodaCond dominate both HavePlace and Max[Place]. That is because [H] violates HavePlace and the /t/ → [H] mapping violates Max[Place]. The step from [paH.ka] to [pa.ka] requires that HavePlace dominate Max. The direct mapping from /patka/ to [pa.ka] is simply unavailable in this theory, because of gradualness, as defined in §2.2. As we will see in the next section, the unavailability of this direct mapping is a crucial element of the explanation for the coda/onset asymmetry.

The analysis so far has been conducted in the realm of the hypothetical. We will therefore turn now to an authentic and familiar example, cluster simplification in Diola Fogny (Niger-Congo, Senegal and Gambia) (Sapir 1965, Kiparsky 1973, Itô 1986). Medial codas are deleted (10), except for nasals followed by homorganic stops (see §3.3). By the logic of (9), deleting a coda involves passing through a step where the coda is reduced to the Placeless consonant denoted by [H].

(10) *Cluster simplification in Diola Fogny* (Sapir 1965)

underlying	*surface*	
uʤu**k**-ʤa	u.ʤu.ʤa	'if you see'
le**t**-ku-ʤaw	le.ku.ʤaw	'they won't go'
ko**b**-kob-en	ko.ko.ben	'yearn for'
a-ʤa**w**-bu-ŋar	a.ʤa.bu.ŋar	'voyager'
na-la**ɲ**-laɲ	na.la.laɲ	'he returned'
na-joke**n**-joken	na.jo.ke.jo.ken	'he tires'
na-waɲ-a**m**-waɲ	na.wa.ɲa.waɲ	'he ploughed for me'

Tableau (11) demonstrates harmonic improvement in the HS derivation necessary to effect the mapping /uʤuk-ʤa/ → [u.ʤu.ʤa].

(11) *Harmonic improvement in* <u.ʤuk.ʤa, u.ʤuH.ʤa, u.ʤu.ʤa>

/uʤuk-ʤa/	CodaCond	HavePlace	Max[Place]	Max
a. u.ʤuk.ʤa *is less harmonic than*	*!			
b. u.ʤuH.ʤa *is less harmonic than*		*!	*	
c. u.ʤu.ʤa			*	*

Examples like [le.ku.ʤaw] show that word-final consonants are not subject to deletion. The phonological literature offers various explanations for this, and nearly all are compatible with the HS analysis above. In Itô (1986), Diola Fogny word-final consonants are licensed by extraprosodicity. In Goldsmith (1990), word-final position can have its own licensing properties. In Piggott (1991, 1999), Diola Fogny word-final consonants are the onsets of empty-headed syllables. In the Itô, Goldsmith and Piggott analyses, then, word-final consonants simply do not violate CodaCond. Krämer (2003) takes a somewhat different approach: Diola Fogny word-final consonants are protected by a right-edge positional faithfulness constraint that dominates CodaCond. The licensing-by-cue approach of Steriade (1999a, b) and Côté (2000) takes yet another tack: CodaCond is replaced by a constraint against Place specifications with poor perceptual cues, and those cues are stronger in word-final codas than in word-medial codas (Côté 2000: ch. 5). This too is completely compatible with the analysis proposed here; constraints determine the phonetic realisation of Place, and the constraint against weakly cued Place replaces CodaCond in the ranking above. Indeed, I know of only one approach to the immunity of word-final consonants that is truly incompatible with the HS analysis, Yip's (1991) Cluster Condition. It is discussed in the next section.

3.2 The coda/onset asymmetry in deletion

We now have the tools necessary to solve half of the problem introduced in §1: when a medial cluster simplifies, the first consonant deletes and the second one doesn't. Deletion of the first consonant is a consequence of the ranking in (9) and (11), which favours an HS derivation that first deletes the Place node and then the remainder of the would-be coda consonant: <pat.ka, paH.ka, pa.ka>. Neither this ranking nor any other permutation of those constraints will produce a harmonically improving, gradual derivation that deletes the second consonant. The reasons are worth exploring in detail.[5]

[5] Like Wilson (2001: 149, 171n), I set aside cases where clusters appear to simplify by deleting the more sonorous consonant, presumably on the grounds that it is an inferior onset according to the Margin hierarchy of Prince & Smolensky (1993). This pattern is particularly evident in simplification of onset clusters in child

Direct deletion of the second consonant in a medial cluster is ruled out by the gradualness requirement. For example, <pat.ka, pa.ta> deletes [t]'s Place feature and the balance of its features in a single step; that is prohibited under the assumptions in §2.2. Therefore, the only properly gradual way to simplify a medial cluster by deleting the second consonant is with an HS derivation like <pat.ka, pat.Ha, pa.ta>.

But this derivation is ruled out because it is not harmonically improving. For <pat.ka, pat.Ha, pa.ta> to be harmonically improving, its first step <pat.ka, pat.Ha> must also be harmonically improving. But <pat.ka, pat.Ha> is not harmonically improving under any ranking of the four constraints in (9) and (11). Tableau (12) shows that [pat.ka] harmonically bounds [pat.Ha] relative to input /patka/ within the scope of this constraint set.[6]

(12) *Harmonic bounding of* <pat.ka, pat.Ha>

/patka/	CodaCond	HavePlace	Max[Place]	Max
a. pat.ka *is **more** harmonic under every ranking than*	*			
b. pat.Ha	*	*	*	

In general, if the path from A to C must go by way of B because of the gradualness requirement, then it is not enough for the mapping A → C to improve harmony; the mappings A → B and B → C must improve harmony as well. Therefore, no HS derivation <A, B, C> can ever be possible, in any language, if A harmonically bounds B. Because of the harmonic bounding result in (12), no language will permit the HS derivation <pat.ka, pat.Ha> under this constraint set. And if <pat.ka, pat.Ha> is ruled out, then so is <pat.ka, pat.Ha, pa.ta>. Although the *mapping* /patka/ → [pa.ta] improves harmony under some ranking of these constraints (i.e. the one in (9) and (11)), the *derivation* necessary to accomplish this mapping does not display monotonic harmonic improvement. That is why /patka/ → [pa.ta] is possible in classic OT but not in HS.

This example can be used to introduce a useful concept from optimisation theory, the LOCAL MINIMUM. Imagine a ball rolling down a bumpy hill. As it descends, it loses potential energy. If it reaches the bottom of the hill, then it has found the global minimum of potential energy. If it gets

phonology, such as the forms [gɪn] *skin* and [so] *snow* reported by Gnanadesikan (2004: 78). Gnanadesikan argues that coalescence rather than deletion is involved here. Coalescence is covert in the examples just cited but overt in words like [fok] *smoke*, which merges the sonority of /s/ with the place of /m/. De Lacy (2002) makes a similar case for Pali, the language that Wilson mentions in this regard.

6 A harmonically bounds B if A has a proper subset of B's violation marks (Samek-Lodovici 1992, Samek-Lodovici & Prince 1999, 2005). This means that B can never beat A under any ranking of the constraints whose violation marks are being examined.

stuck at a bump, then it has reached a local minimum that is not the global minimum. Translating into OT terms, potential energy is equivalent to potential for harmonic improvement. Classic OT always finds the candidate that is the global minimum of potential for further harmonic improvement. HS sometimes gets stuck at a local minimum.

The /patka/ example will illustrate. Suppose that deletion of the /t/ is ruled out by a constraint requiring faithfulness to segments in initial syllables (Beckman 1997, 1998). Suppose too that other ways of fixing this cluster, such as vowel epenthesis, are excluded by high-ranking constraints. In that case, the global minimum of potential for harmonic improvement is [pa.ta]. Classic OT finds this global minimum without difficulty because it compares candidates that differ from the input without limitation. But HS, with gradualness as defined in §2.2, cannot get from /patka/ to [pa.ta] because there is a bump along the way. The bump is [pat.Ha], a form that is less harmonic than [pat.ka]. HS therefore gets stuck at the local minimum [pat.ka].

Classic OT always finds the global minimum – the output form that is more harmonic than all other candidates. HS is not guaranteed to find the global minimum – sometimes it gets stuck in a local minimum when all routes to the global minimum involve decreasing harmony before it can increase. HS's propensity to get stuck in a local minimum sounds like a liability, but the typological results discussed here and in McCarthy (2007b, forthcoming) show that it is arguably an advantage that HS has over parallel OT.

Back to (12). Harmonic bounding results like this one are always determined relative to some set of constraints; an outcome that is harmonically bounded under one constraint set may not be bounded under another. In particular, if CodaCond is replaced by the Cluster Condition of Yip (1991) (see also Prince 1984), then the typological result in (12) no longer goes through. The Cluster Condition prohibits a sequence of Place nodes. It is violated by *[pat.ka], because of the [tk] sequence. The problem is that <pat.ka, pat.Ha> does improve performance on the Cluster Condition, though not on CodaCond. Therefore, the results here rely on rejecting the Cluster Condition as a member of OT's universal constraint set Con. For other reasons to doubt the Cluster Condition, see McCarthy & Taub (1992: 364–365), Jun (1995: 23–24), Côté (2000: 51) and Scholz (2003: 147).

Harmonic bounding also forecloses another imaginable path of cluster simplification: delinking but not deleting a Place feature.[7] (I use the notation X/F to represent the word X with floating feature F.) Neither of the derivations <pat.ka, paH.ka/coronal> and <pat.ka, pat.Ha/dorsal> improves performance on CodaCond. As defined in (6), CodaCond is violated by any Place feature without an onset linkage, and floating features perforce lack onset linkage. Since the segments left behind after Place

[7] I am grateful to Marc van Oostendorp for raising this issue.

delinking violate HAVEPLACE, the first step in each of these derivations is harmonically bounded.

(13) *Harmonic bounding of Place delinking*

/patka/	CODACOND	HAVEPLACE	MAX[Place]	MAX
a. pat.ka *is **more** harmonic under every ranking than*	*			
b. paH.ka/cor pat.Ha/dors	*	*		

The HS analysis of the coda/onset asymmetry finds support from a surprising quarter: cases where the onset actually does delete. The theory here predicts that the coda/onset asymmetry will not hold when the deleted consonant is Placeless in underlying representation. The reason: although CODACOND can compel loss of Place only in codas, loss of Place is not a precondition for deletion when the affected segment already lacks Place. This prediction is borne out in Tonkawa (Coahuiltecan, Oklahoma). Tonkawa [h] has the following distribution (Hoijer 1946: 291–292): it occurs initially ([henox] 'pretty') and intervocalically ([ʔahen] 'daughter'), it is banned from codas and it is also banned from postconsonantal onsets, leading to alternations like those in (14).

(14) /h/-*deletion from postconsonantal onsets in Tonkawa*

underlying	*surface*	
nes-**h**e-ʦane-oʔs	neseʦnoʔs	'I cause him to lie down'
nes-**h**a-na-kapa-	nesankapa-	'to cause to be stuck'

Deletion of [h] can occur in a single step of a properly gradual HS derivation: <…, nesheʦanoʔs, neseʦanoʔs, …>. This step improves harmony in Tonkawa because HAVEPLACE dominates MAX. The preservation of initial and intervocalic [h] shows that HAVEPLACE is itself dominated by ONSET.

3.3 The coda/onset asymmetry in Place assimilation

Like deletion, Place assimilation targets the first and never the second consonant in an intervocalic cluster, so we find mappings like /panpa/ → [pam.pa], but never /panpa/ → [pan.ta]. The explanation follows straightforwardly from what we have already seen. Because of gradualness, a nasal that is specified for Place in underlying representation must lose its Place in one step and gain a new Place by spreading in the following step: <pan.pa, paN.pa, pam.pa>.

This view of Place assimilation can be illustrated with some additional data from Diola Fogny in (15). Nasals assimilate in Place to following stops and affricates.

(15) *Assimilation in Diola Fogny* (Sapir 1965)

underlying	*surface*	
naʤum-to	na.ʤu**n**.to	'he stopped'
ni-maŋ-maŋ	ni.ma**m**.maŋ	'I want'
ni-ɲan-ɲan	ni.ɲaŋ.**ɲ**an	'I cried'
ni-gam-gam	ni.ga**ŋ**.gam	'I judge'
pan-ʤi-maɲʤ	pa**ɲ**.ʤi.maɲʤ	'you (PL) will know'
na-tiŋ-tiŋ	na.ti**n**.tiŋ	'he cut through'
ku-boɲ-boɲ	ku.bo**m**.boɲ	'they sent'

The resulting homorganic cluster has a single Place feature shared by the coda and the onset. CodaCond is satisfied because, as defined in (6), it does not so much ban Place from codas as require that Place be in an onset. Harmonic improvement in the HS derivation <na.ʤum.to, na.ʤuN.to, na.ʤun.to> is demonstrated by the following tableau.

(16) *Harmonic improvement in* <na.ʤum.to, na.ʤuN.to, na.ʤun.to>

/naʤum-to/	CodaCond	HavePlace	Max[Place]	NoLink[Place]
a. na.ʤum.to *is less harmonic than*	*!			
b. na.ʤuN.to *is less harmonic than*		*!	*	
c. na.ʤun.to			*	*

For the reasons given in the previous section, loss of Place can be harmonically improving in codas but not onsets. The derivation <pap.ŋa, pap.Na, pap.ma> is impossible because it is harmonically bounded in its first step, <pap.ŋa, pap.Na>.

(17) *Harmonic bounding of* <pap.ŋa, pap.Na>

/papŋa/	CodaCond	HavePlace	Max[Place]	Max
a. pap.ŋa *is **more** harmonic under every ranking than*	*			
b. pap.Na	*	*	*	

Because <pap.ŋa, pap.Na, pap.ma> is an impossible derivation and there is no other gradual path from /papŋa/ to [pap.ma], the mapping /papŋa/ → [pap.ma] is impossible as well. And although <pap.ŋa, pap.ma> is harmonically improving, it is ruled out by gradualness. As I explained in §2.2, gradualness requires feature-changing assimilation to be decomposed into separate feature-deleting and feature-filling steps.

As in §3.2, we can find independent support for this explanation of the coda/onset asymmetry by looking at cases where the asymmetry does *not* hold. There are three situations to consider: Place assimilation when the targeted consonant is a Placeless laryngeal, Place assimilation when the targeted consonant is epenthetic, and assimilation of features other than Place.

If one of the consonants in a cluster is a Placeless laryngeal, then Place deletion is not a necessary precursor to Place assimilation (not all laryngeals are Placeless; see §3.4). Obviously, a Placeless coda can be targeted for assimilation, but so can a Placeless onset. That is why there can be languages like Arbore and Afar (both Cushitic, Ethiopia), where onset /h/ is targeted by assimilation.

(18) a. *Onset* /h/*-assimilation in Arbore* (Hayward 1984: 66–67)

underlying	*surface*	
mín-h-áw	mín**n**aw	'my house'
ʔabás-h-áw	ʔabás**s**aw	'my stew'

b. *Bidirectional* /h/*-assimilation in Afar* (Bliese 1981: 240–241)

underlying	*surface*	
si'doːx haj'to	si'doːx **x**aj'to	'third'
'tamahih sabba'tah	'tamahi**s** sabb'atah	'because of this'

The explanation for the coda/onset asymmetry in Place assimilation rests on the harmonic bounding of Place deletion in onsets, as shown in (17). But when the onset is already Placeless, there is no problem with harmonic bounding of the Place-deletion step, and spreading Place from coda to onset provides a way of satisfying CodaCond.

The second situation where the coda/onset asymmetry does not hold involves targeting of an epenthetic onset consonant for Place assimilation. Loss of Place is not a necessary precondition for assimilation when the affected segment has no underlying structure to be faithful to, so it is predicted that the coda/onset asymmetry will not hold in such cases. This prediction is borne out in Lardil (Hale 1973). In this language, /CVC/ words are usually augmented by adding [Ca], where C is a stop that is homorganic with the preceding root-final consonant (19).

(19) *Epenthetic onset assimilation in Lardil*

underlying	*surface*	
maɽ	maɽ**ʈ**a	'hand'
ɽil	ɽil**t**a	'neck'
kaŋ	kaŋ**k**a	'speech'

Here, an onset consonant assimilates in place to a preceding coda. This is permitted because the onset consonant is epenthetic, so it does not need to go through the harmonically bounded step of onset Place deletion before it can be targeted for spreading of the Place node.

The third situation where the coda/onset asymmetry does not hold is when the assimilating feature is not Place. Manner features can assimilate progressively, as in Arbore /fal-n-e/ → [fálle] '(we) cursed' (Hayward 1984: 79). So can laryngeal features, as in Dutch /krɑb-tə/ → [krɑbdə] 'scratched' (Booij 1995: 58–64, Wetzels & Mascaró 2001). Dependent place features like [distributed] and [anterior] also sometimes assimilate progressively in clusters; for examples, see Kristofferson (2000: 96–100) on progressive assimilation of apicality (i.e. [−distributed]) in Norwegian, and Whitney (1889: 68) on progressive assimilation of palatality (i.e. [−anterior]) in Sanskrit. Nothing in the proposal here would cause us to expect anything different. Codas are targets of Place deletion and subsequent Place assimilation because the existence of CodaCond ensures that Place deletion will improve harmony in systems where it dominates Max[Place]. Constraints on the licensing of other features may and obviously do have different effects.

3.4 Debuccalisation

Deletion of oral Place features from consonants was dubbed debuccalisation by Hetzron (1972), because loss of Place is loss of the constriction in the oral cavity. The result of debuccalisation is a Placeless oral or nasal consonant, which I have been writing as [H] and [N].

In the HS analyses above, debuccalisation is a step on the way toward deletion or assimilation. But with a different ranking, debuccalisation can be the final result. As (20) shows, the candidate HS derivation <pat.ka, paH.ka> is harmonically improving but <pat.ka, paH.ka, pa.ka> is not if Max dominates HavePlace (cf. (9)).

(20) *Ranking for debuccalisation*

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

With this ranking, the HS derivation can never make it as far as [pa.ka], starting from /patka/. Instead, the derivation converges at [paH.ka].

Among the languages with debuccalisation processes are Arbore (21a), which debuccalises glottalised coda consonants, and Kagoshima Japanese (21b), which debuccalises coda stops and nasals derived by apocope.[8]

[8] There are unresolved questions about which oral consonants debuccalise to [ʔ] and which debuccalise to [h]. The possible determinants include the laryngeal features and the stricture of the original consonant. Relevant work includes Fallon (1998: ch. 5) on debuccalisation of ejectives and Vaux (1998) on debuccalisation of fricatives.

(21) a. *Debuccalisation in Arbore* (Hayward 1984: 64)

underlying	*surface*	
beːkˀ-t-aw	beː**ʔ**táw	'my wound'
dˀiːkˀ-t-e	dˀiː**ʔ**te	'she bled'
ʤédˀ-lo	ʤé**ʔ**lo	'this scorpion'

b. *Debuccalisation in Kagoshima Japanese* (Kaneko & Kawahara 2002)

underlying	*surface*	
tobu	to**ʔ**	'fly'
kutsu	ku**ʔ**	'shoes'
kuʧi	ku**ʔ**	'mouth'
inu	i**N**	'dog'
kami	ka**N**	'paper'

Because debuccalisation is a step along the way toward assimilation or deletion, we should not be surprised to find that that debuccalisation sometimes co-occurs with assimilation or deletion, with other constraints determining which outcome is chosen when. Carib of Surinam (Hoff 1968, Gildea 1995) and Arbore (Hayward 1984) provide illustrations. In Carib, coda nasals assimilate in Place to a following stop (22a), but they debuccalise to [ʔ] before another nasal (22b). Assimilation is blocked before nasals because the language has no geminates. In Arbore, plain stops in coda position assimilate (22c), but glottalised stops debuccalise (21a). The differential treatment of glottalised stops is presumably an effect of faithfulness to their underlying [constricted glottis] specification.

(22) a. *Coda assimilation in Carib*

underlying	*surface*	
ekaːnumɨ-potɨ	ekaːnu**m**botɨ	'to run repeatedly'
kɨn-ekaːnumɨ-taŋ	kɨneːkaːnu**n**daŋ	'he will run'
aj-ekaːnumɨ-ko	ajeːkaːnu**ŋ**go	'run!'

b. *Coda debuccalisation in Carib*

underlying	*surface*	
ekaːnumɨ-no	ekaːnu**ʔ**no	'running'

c. *Assimilation in Arbore* (cf. (21a))

underlying	*surface*	
harrag-mé	harra**m**mé	'bead necklaces'
dˀekˀkˀat-mé	dˀekˀkˀa**m**mé	'grindstones'
kut-n-e	kú**n**ne	'we cut (it)'

Besides illustrating one of the consequences of constraint permutation, debuccalisation is also useful in answering a question that several anonymous reviewers have raised about the HS explanation for the coda/onset asymmetry. If Placeless [H] is an intermediate step on the path to deletion or assimilation, then what does this predict about the fate of underlying /ʔ/ and /h/ in the same language? The answer depends on a known ambiguity in the representation of these segments:

(i) In some languages, /ʔ/ and /h/ act as if they are Placeless. They can be targeted for deletion or assimilation in onset position, as in (14) and (18). They can also occur in coda position in languages that enforce CODACOND rigidly (Rice 1992, Rose 1996).[9]

(ii) In other languages, /ʔ/ and /h/ act as if they have [pharyngeal] Place, since they pattern phonologically with the class of guttural consonants, all of which are produced in the uvular, pharyngeal or laryngeal regions of the vocal tract (Hayward & Hayward 1989, McCarthy 1994b).

In light of this ambiguity, predictions about the relationship between [H] and /ʔ/ and /h/ are necessarily rather subtle. If underlying /ʔ/ and /h/ have (or receive) [pharyngeal] Place prior to debuccalisation, then they will behave differently from the truly Placeless result of debuccalisation. Rose (1996: 92–97, 106–107) shows that exactly this occurs in Tigre. Coda /kʔ/ debuccalises to [ʔ]. But Tigre bars coda position to underlying /ʔ/ and /h/, as well as the other [pharyngeal] consonants. This difference shows that the [ʔ] derived by debuccalisation is truly Placeless, but underlying /ʔ/ and /h/ in Tigre are not.

In sum, we expect to find no difference in behaviour between the output of debuccalisation and underlying /ʔ/ and /h/ in languages where /ʔ/ and /h/ are truly Placeless, whereas we do expect to find differences when /ʔ/ and /h/ have [pharyngeal] Place.

So when do underlying /ʔ/ and /h/ have [pharyngeal] Place? One possibility is that each language freely determines whether its laryngeals have Place (Bessell 1992, Bessell & Czaykowska-Higgins 1992, McCarthy 1994b). A more restrictive alternative is that laryngeals have [pharyngeal] Place if and only if there are other [pharyngeal] consonants in the language (Rose 1996). The latter is too restrictive, as it turns out. Jahai (Austro-Asiatic, Malaysia) has no [pharyngeal] consonants except [ʔ] and [h], but it also satisfies one of the main criteria for [pharyngeal] place, vowel lowering. In reduplicated words of the form $C_1V_1C_2$-$C_1V_2C_2$, the quality of V_1 is determined phonologically (Burenhult 2001): [a] if C_2 is [ʔ] or [h], [i] if C_2 is palatal and [ə] otherwise. Jahai, then, is a language with [pharyngeal] Place in [ʔ] and [h], but nothing in the system of contrasts forces this. With our present understanding, then, the presence of a [pharyngeal]

[9] One of the first arguments for Placeless /ʔ/ and /h/ was based on the observation that they are often transparent to total vowel harmony (Aoki 1968, Steriade 1987, 1995, Stemberger 1993, Lloret 1995, Ọla Orie & Bricker 2000). The idea is that total vowel harmony requires spreading a vowel's Place node, and /ʔ/ and /h/ are transparent because they have no Place node. This argument has been undermined by two later discoveries: other consonants, such as uvulars and coronals, can also be transparent to harmony (McCarthy 1994a, Gafos & Lombardi 1999), and /ʔ/ and /h/ are sometimes transparent to less than total vowel harmony (Odden 1991: 275).

specification in underlying laryngeals is simply another dimension of language difference.

3.5 Additional steps on the path to deletion?

HS derivations like <u.ʤuk.ʤa, u.ʤuH.ʤa, u.ʤu.ʤa> naturally provoke a question about gradualness: segments have more structure than just a Place node and a Root node, so are additional intermediate steps required? The explanation of gradualness in §2.2 offers some guidance in answering this question: properties that are not protected by faithfulness can change with no impact on gradualness. For example, it has been claimed that the constraint Max(μ) does not apply to the moras associated with non-geminate codas (Bermúdez-Otero 2001, Campos-Astorkiza 2004). If this is correct, then deleting these moras should not require a separate derivational step.

For reasons given in §2.2, features protected by Ident rather than Max can delete along with their host segment without requiring a separate derivational step. Davis & Shin (1999: 290–292) argue that features differ systematically in this respect. Stricture features [sonorant] and [continuant] are plausible candidates for Ident status, since they never seem to exhibit independence from their segmental hosts.

On the other hand, Lombardi (2001) argues that coda devoicing is a process of [voice] deletion, violating Max[voice]. Her argument is based on the observation that languages never accomplish coda devoicing by deleting the whole consonant. Classic OT with Ident[voice] predicts that such a language could exist because of Ident's vacuous satisfaction property.

(23) *Classic OT with* Ident[voice]

/padma/	NoVcdCoda	Ident[voice]	Max
☞ a. pa.ma			*
b. pad.ma	*!		
c. pat.ma		*!	

Lombardi observes that this problem does not arise with Max[voice], however. As tableau (24) shows, deletion of a voiced coda violates both Max[voice] and Max, whereas devoicing it violates only Max[voice]. Since both mappings produce a result that satisfies the markedness constraint NoVcdCoda, the more faithful candidate has to win.

(24) *Classic OT with* Max[voice]

/padma/	NoVcdCoda	Max[voice]	Max
☞ a. pat.ma		*	
b. pad.ma	*!		
c. pa.ma		*	*!

Though initially attractive, the move to MAX[voice] makes an unwelcome prediction. If MAX[voice] dominates CODACOND, which itself dominates MAX, then voiceless obstruent codas will be deleted, but voiced obstruent codas will not. We therefore get a language where /patka/ becomes [pa.ka], but /padma/ becomes [pad.ma].

(25) a. *Deletion of voiceless codas in classic OT*

/patka/	MAX[voice]	CODACOND	MAX
☞ i. pa.ka			*
ii. pat.ka		*!	

b. *With preservation of voiced codas*

/padma/	MAX[voice]	CODACOND	MAX
☞ i. pad.ma		*	
ii. pa.ma	*!		*

With this ranking, we get a language that has voiced obstruent codas but no voiceless ones. That does not seem to happen.

This typological result indicates that there is something amiss with the MAX[voice] idea. But if we retreat to IDENT[voice], how will we rule out the unwanted result in (23)? Under the assumptions about gradualness in §2.2, HS does not need MAX[voice] to explain why NOVCDCODA is unable to compel coda deletion. Instead, HS can rely on the fact that NOVCDCODA is unable to compel Place deletion, and Place deletion is an essential step on the path to deleting the entire coda consonant. The Place-deleting first step in the chain <pad.ma, paH.ma, pa.ma> does not improve performance on NOVCDCODA, so this constraint acting alone cannot produce coda deletion in HS.

(26) *<pad.ma, paH.ma, pa.ma> *with* NOVCDCODA

/padma/	NOVCDCODA	MAX[Place]	CODACOND	MAX
a. pad.ma *is **more** harmonic than*	*		*	
b. paH.ma *is less harmonic than*	*	*		
c. pa.ma		*		*

If, in addition, IDENT[voice] dominates NOVCDCODA, then [pad.ma] is a local minimum. The global minimum, [pa.ma], is unattainable because there is no harmonically improving gradual path to it from /padma/. Classic OT always finds the global minimum because it evaluates the results of all processes together, in parallel. That is why classic OT with IDENT[voice] makes the bad prediction in (23).

At the beginning of this section, I asked whether deleting a coda consonant might involve more intermediate steps than just debuccalisation. We know from §2.2 that the answer to this question depends on whether there are any other Max[feature] constraints besides Max[Place]. The current answer is no, since the best candidate for such a constraint, Max[voice], turns out to be problematic and, in HS, unnecessary.

3.6 Target and trigger conditions

Jun (1995, 2004) did a typological survey to discover the conditions that languages impose on the segment that undergoes Place assimilation ('target conditions') or the segment from which the assimilating Place feature spreads ('trigger conditions').

Certain target conditions are rather common. In English and Diola Fogny (15), for example, nasals undergo Place assimilation, but plosives do not. In English and Catalan, coronals undergo Place assimilation but labials and velars do not.

(27) *Place assimilation in Catalan* (Mascaró 1976, Kiparsky 1985: 95)

	underlying	*surface*	
a.	son pɔks	som pɔks	'they are few'
	son kars	soŋ kars	'they are expensive'
cf.	son uniks	son uniks	'they are unique'
b.	som uniks	som uniks	'we are unique'
	som dɛw	som dɛw	'we are ten'
	tiŋ paw	tiŋ paw	'I have peace'

In principle, the effect of target conditions could be obtained by elaborating the markedness constraint CodaCond or the faithfulness constraint Max[Place]. For example, suppose there is a coronal-specific constraint CodaCond$_{coronal}$. In Catalan, CodaCond$_{coronal}$ dominates Max[Place], but unadorned CodaCond is dominated by Max[Place]. Thus, there is a harmonically improving derivation <son kars, soN kars, soŋ kars>, but there is no gradual, harmonically improving path from /tiŋ paw/ to *[tim paw].

(28) a. *Harmonic improvement in* <son kars, soN kars, soŋ kars>

/son kars/	CodaCond$_{cor}$	HavePlace	Max [Place]	CodaCond	NoLink [Place]
i. son.kars *is less harmonic than*	*!			*	
ii. soN.kars *is less harmonic than*		*!	*		
iii. soŋ.kars			*		*

b. *No harmonic improvement in* <tiŋ.paw, tiN.paw, tim.paw>

/tiŋ paw/	CODA COND$_{cor}$	HAVEPLACE	MAX [Place]	CODA COND	NOLINK [Place]
i. tiŋ.paw *is **more** harmonic than*				*	
ii. tiN.paw *is less harmonic than*		*	*		
iii. tim.paw			*		*

Likewise, Place assimilation can be limited to target nasals, as in Diola Fogny, if there is a nasal-specific version of CODACOND.

The overall proposal here is equally compatible with the faithfulness-based approach to target conditions taken by Jun (1995, 2004) and de Lacy (2002, 2006). Let MAX[labial|dorsal] stand for the constraint or constraints violated when the marked Place features [labial] or [dorsal] are deleted. The Catalan pattern of coronal targeting is obtained if MAX[labial|dorsal] dominates CODACOND, while MAX[coronal] is dominated by CODACOND.

(29) a. *Catalan with low-ranking* MAX[cor]

/son kars/	MAX [lab|dors]	CODA COND	HAVE PLACE	MAX [cor]	NOLINK [Place]
i. son.kars *is less harmonic than*		*!			
ii. soN.kars *is less harmonic than*			*!	*	
iii. soŋ.kars				*	*

b. *And high-ranking* MAX[lab|dors]

/tiŋ paw/	MAX [lab|dors]	CODA COND	HAVE PLACE	MAX [cor]	NOLINK [Place]
i. tiŋ.paw *is **more** harmonic than*		*			
ii. tiN.paw *is less harmonic than*	*		*		
iii. tim.paw	*				*

The markedness- and faithfulness-based approaches to TARGET conditions appear to be equally compatible with the HS analysis of the coda/onset asymmetry. We will now see that a TRIGGER condition on place assimilation has to be analysed with faithfulness, since a markedness analysis would undermine the HS explanation for the coda/onset asymmetry.

In Korean and Latin, non-coronals trigger Place assimilation but coronals do not (Hale & Buck 1966, Devine & Stephens 1977, Kim-Renaud 1986, Jun 1996, 2004).

(30) a. *Korean Place assimilation*

	underlying	*surface*	
	mit-ko	mi**k**ko	'believe and'
	kot-palo	ko**p**palo	'straight'
	ip-ko	i**k**ko	'wear and'
vs.	ik-ta	i**k**ta	'ripe (DECL)'
	ip-ta	i**p**ta	'wear (DECL)'

b. *Latin Place assimilation*

	underlying	*surface*	
	ad-kidoː	a**k**kidoː	'I fall down'
	ob-kidoː	o**k**kidoː	'I die'
	ad-paːreoː	a**p**paːreoː	'I appear'
vs.	skriːb-t-us	skriː**p**tus	'written (NOM SG)'
	fak-t-us	fa**k**tus	'made (NOM SG)'

In Korean, dorsal + labial clusters are allowed without assimilation: [ʧak^{h}pa] 'destruction'. They are disallowed in Latin, but the morphology provides no opportunities to see whether they assimilate.

In Korean and Latin, place assimilation does not occur when the second consonant in the cluster is a coronal. In principle, we could differentiate CODACOND and MAX[Place] by the Place of the following consonant. There could be a high-ranking markedness constraint CODACOND$_{/__\text{lab|dors}}$ that is violated by *[mitko], but not by [ikta]. Or there could be a low-ranking faithfulness MAX[Place]$_{/\_\_\text{cor}}$ that is violated by the mapping /ik-ta/ → [iHta], but not by the mapping /mit-ko/ → [miHko]. In keeping with his overall faithfulness-based approach to trigger and target conditions, Jun opts for the latter. The HS analysis of the coda/onset asymmetry also requires a faithfulness-based approach to trigger conditions.[10]

From the HS perspective, the problem with CODACOND$_{/__\text{lab|dors}}$ is that it can be satisfied in two different ways: debuccalising the coda or debuccalising the following onset. From input /mit-ko/, two harmonically improving HS derivations should be possible: <mit.ko, miH.ko, mik.ko> and *<mit.ko, mit.Ho, mit.to>. The problem is that [miH.ko] and [mit.Ho] both improve performance on CODACOND$_{/__\text{lab|dors}}$. The HS explanation for the coda/onset asymmetry rests on the assumption that there are no constraints like the Cluster Condition discussed in §3.2. That is, there are no constraints that specifically militate against sequences of non-identical Place specifications in heterorganic clusters. CODACOND$_{/__\text{lab|dors}}$ is such a constraint. This is perhaps less obvious in the case of CODACOND$_{/__\text{lab|dors}}$, since the reference to onset place is framed as a contextual condition, but the effect is the same.

As I noted previously, Jun's (1995, 2004) analysis of trigger conditions, like his analysis of target conditions, is couched in faithfulness terms.

[10] I am grateful to Karen Jesney and an anonymous reviewer for bringing this issue to my attention.

A constraint with the force of MAX[Place]$_{/\_\_\mathrm{cor}}$ prevents coda debuccalisation before a coronal, and so Place assimilation dies aborning. With MAX[Place]$_{/\_\_\mathrm{cor}}$ ranked above undifferentiated CODACOND, neither *<ip.ta, iH.ta, it.ta> nor *<ip.ta, ip.Ha, ip.pa> is harmonically improving in their first steps. Furthermore, the latter is harmonically bounded under exactly the same conditions as the onset-altering derivation in (17). The HS explanation for the coda/onset asymmetry emerges unscathed.

There is a larger lesson to be found here. In an HS derivation, harmonic improvement is really a matter of becoming progressively less marked, relative to the language's constraint hierarchy. Faithfulness constraints are only relevant insofar as they stop progress toward greater unmarkedness (so every derivation does not end in [ba]) or choose among alternate paths to greater unmarkedness (such as epenthesis *vs*. deletion). For this reason, innovations in markedness constraints are a greater threat to restrictive typologies obtained in HS than innovations in faithfulness constraints. New markedness constraints open up new derivational paths that can lead to surface forms that had previously been unobtainable. This is a two-edged sword. In this section, the new markedness constraint proved to be a bad idea. In the next section, though, a different markedness innovation permits a necessary departure from perfect coda/onset asymmetry.

3.7 Suffix-initial deletion and assimilation

Wilson (2001) suggests that the coda/onset asymmetry in deletion may not hold at root-suffix juncture. Jun (1995) says the same thing about the coda/onset asymmetry in Place assimilation (see also Borowsky 2000 and Hyman 2001).

The evidence comes from cases where a consonant-final root meets a consonant-initial suffix, and the second consonant is affected by deletion or assimilation rather than the first. Most examples cited by Wilson or Jun involve alternations of a single suffix, such as the Ibibio negative (Akinlabi & Urua 2002), the Gidabal 'to get' suffix (Kenstowicz & Kisseberth 1977: 181), a verbal agreement suffix in Kambaata (Hudson 1980, Sim 1985, 1988) and the Dutch diminutive. The last of these is exemplified in (31).

(31) *Dutch diminutive* (Booij 1995: 70)

	underlying	*surface*	
	rim-tjə	rim**p**jə	'belt (DIM)'
	konɪŋ-tjə	konɪŋ**k**jə	'king (DIM)'
cf.	re-tjə	retjə	'deer (DIM)'

A standard phonological analysis of Dutch takes the underlying form of the diminutive suffix to be /-tjə/, with feature-changing progressive Place assimilation in words like [rimpjə] or [konɪŋkjə] (Booij 1995: 69–73). But since no other Dutch suffix has this behaviour, it is equally reasonable to suppose that the diminutive suffix is /-Cjə/, where C denotes a segment unspecified for Place. It gets Place by spreading from a preceding consonant, and otherwise defaults to coronal (van der Hulst 1984: 127, Lahiri & Evers 1991, van Oostendorp 1997: 234ff, van de Weijer 2002: 203). Dutch therefore escapes the consequences of the coda/onset asymmetry for exactly the same reason that Lardil does: the affected consonant has no underlying Place to be faithful to.

This analytic move is not available for another of Jun's (1995) examples, however. A process of suffix-consonant place assimilation in Musey (Chadic, Chad) is analysed in detail by Shryock (1993).[11] Musey has four consonant-initial suffixes: /-na, -da, -ɗi, -kijo/. When the preceding root ends in a vowel, glide or [ɾ], these suffixes preserve their underlying forms, except that /-da/ lenites to [-ɾa] and /-kijo/ lenites to [-gijo] by regular processes. But when the root ends in an oral or nasal stop, the suffix-initial consonant assimilates in Place to the root-final one.

(32) *Musey affix assimilation* (*tones suppressed*)

	underlying	surface	
a.	*masculine* /-na/		
	hap-na	hap**m**a	'white'
	zoŋ-na	zoŋ**ŋ**a	'young man'
	cf. sa-na	sana	'person'
b.	*feminine* /-da/		
	tok-da	tok**k**a	'meeting'
	kolom-da	kolom**b**a	'mouse'
	cf. goːni-da	goːniɾa	'hyena'
c.	*negative* /-ɗi/		
	salap-ɗi	salap**p**i	'weave'
	ʔeŋ-ɗi	ʔeŋ**g**i	'strength'
	cf. ka-ɗi	kaɗi	'exist'
d.	*intensifier* /-kijo/		
	dut-kijo	dut**t**ijo	'pick fruit'
	hum-kijo	hum**b**ijo	'hear'
	cf. toː-kijo	toːgijo	'sweep'

If the root ends in a continuant [f], [s], [ɬ] or [l], then Place and manner assimilate from root to suffix: /giɾif-kijo/→[giɾiffijo] 'kneel'. These four clusters are the only source of heteromorphemic clusters in the language, so the evidence is necessarily somewhat limited.

Obviously, Musey does not respect the coda/onset asymmetry at root-suffix juncture. An explanation is required. Jun's (1995) analysis calls on

[11] I am grateful to Jongho Jun for providing me with a copy of Shryock's unpublished paper.

the distinction between root- and affix-faithfulness constraints proposed in McCarthy & Prince (1995, 1999). The general idea is that the inventory of phonological objects allowed in affixes is often a less marked proper subset of the inventory in roots. If faithfulness constraints come in root and affix versions, with the root version never ranked lower, then this observation is explained. A side-effect is that phonological alternations may preferentially affect affixes when the choice is between being unfaithful in a root or an affix. In Jun's classic OT analysis, Musey exemplifies this latter behaviour: faithfulness to root Place takes precedence over faithfulness to affix Place.

(33) *Musey in classic OT*

/kolom-da/	CODACOND	IDENT[Place]$_{rt}$	IDENT[Place]$_{aff}$
☞ a. ko.lom.ba			*
b. ko.lon.da		*!	
c. ko.lom.da	*!		

This strategy will not help with the HS analysis of Musey, however. The problem is that the first step of the derivation <ko.lom.da, ko.lom.Ha, ko.lom.ba> does not improve harmony relative to CODACOND, since the [m] of [ko.lom.Ha] has a [labial] Place feature in coda position. Although this Place feature could be licensed at the next step of the derivation by spreading to the following onset, HS requires harmonic improvement at *every* step, so <ko.lom.da, ko.lom.Ha, ko.lom.ba> is impossible if CODACOND is the only active constraint that favours deletion of Place.

Some recent research results suggest a different approach. There are cases where restrictions on affixes cannot be accounted for with high-ranking root faithfulness. This leads to the conclusion that affix-specific *markedness* constraints are required. Some examples: (i) Padgett (1995) argues that Place assimilation in Gã requires a constraint against complex segments in affixes to block total Place assimilation; (ii) Walker (1998) presents an analysis of Tuyuca in which an affix-specific markedness constraint is needed to block nasal spreading; (iii) Bat-El (forthcoming) shows that an affix-domain OCP constraint is required in Modern Hebrew; (iv) Gouskova (2007) and Flack (2007) show that certain templatic requirements must be analysed with affix-specific markedness constraints.

With affix-specific markedness constraints, a proper HS analysis of Musey becomes possible.

Markedness constraints like *CORONAL and *DORSAL are quite standard in OT (Prince & Smolensky 1993, de Lacy 2002, 2006, Lombardi 2002 and many others). Affix-specific versions of these constraints – that is, *CORONAL$_{aff}$ or *DORSAL$_{aff}$ – will be violated by tokens of these features that belong to affixal morphemes. For example, [kolom-da] violates *CORONAL$_{aff}$ because it contains a token of [coronal] belonging to the affixal morpheme [-da]. This token of coronal is missing from [kolom-Ha], which therefore obeys *CORONAL$_{aff}$. The ultimate output [kolom-ba] also obeys this constraint, because the token of [labial] associated with the affix-initial [b] does not belong to the affixal morpheme. (Consistency of Exponence ensures that the underlying morphological affiliations of phonological material are always preserved; McCarthy & Prince 1993.) We can therefore discern a harmonically improving path from /kolom-da/ to [ko.lom.ba] via [ko.lom.Ha].[12]

(34) *Harmonic improvement in Musey*

/kolom-da/	*COR$_{aff}$	HAVEPLACE	MAX[Place]	NOLINK[Place]
a. ko.lom.da *is* ***more*** *harmonic than*	*!			
b. ko.lom.Ha *is less harmonic than*		*!	*	
c. ko.lom.ba			*	*

*DORSAL$_{aff}$ must also dominate HAVEPLACE to account for assimilation of the initial consonant in the suffix /-kijo/. If *DORSAL universally dominates *CORONAL, as is often assumed, then this ranking follows from transitivity of constraint domination.

This leaves one detail to account for: the preservation of coronal and dorsal place in affixes after root-final vowels, glides and [ɾ]: /ka-ɗi/ → [ka.ɗi], *[ka.Hi]. The explanation derives from the general phonotactics of the language: the Placeless consonants [h] and [ɦ] are allowed only word-initially. We already have the explanation for why they do not occur pre- and postconsonantally: HAVEPLACE dominates NOLINK[Place], so any would-be VChV sequence will undergo Place assimilation (cf. Arbore and Afar in (18)). The only other context where [h] or [ɦ] could in principle occur but do not is after a vowel, glide or [ɾ] – exactly the environment where *CORONAL$_{aff}$ and *DORSAL$_{aff}$ are unable to compel Place deletion. Therefore, the same markedness constraint(s) can block loss of Place after a vowel, glide or [ɾ], and forbid underlying Placeless consonants from surfacing faithfully in this context.

4 Further typological consequences

4.1 Introduction

The assumptions about gradualness in §2.2 entail that deletion of a Place-bearing consonant cannot be accomplished in a single step of an HS derivation. Two steps at least are required: one to delete the targeted consonant's Place node, and another to delete the rest of its structure.

[12] It is also possible to construct an analysis where CODACOND rather than HAVEPLACE is the impetus for spreading in (34).

Because of HS's basic architecture, specifically the GEN → EVAL → GEN … loop, each of these deletion steps must individually improve harmony.

Deletion of codas is possible because CODACOND prohibits Place in codas, so deleting a coda's Place node is a way of improving performance on this constraint. A different markedness constraint could also disfavour codas without specifically mentioning the Place node. Deleting the Place node would not improve performance on this constraint. Since deleting the Place node is the required path to consonant deletion, such a constraint is predicted not to cause consonant deletion. As we will see, this prediction seems to be correct. It provides additional support for HS by resolving other TMR problems that arise in classic OT.

4.2 Elimination of CVːC syllables

Many languages take pains to avoid CVːC syllables. These syllables violate markedness constraints against exceeding two moras or against having a coda that does not support its own mora (Sherer 1994). In classic OT, permuting the ranking of MAX, DEP and MAX(μ) predicts three distinct ways of eliminating CVːC.

(i) If MAX and DEP dominate MAX(μ), then CVːC syllables will be eliminated by vowel shortening. This occurs in Cairene Arabic, for example (Mitchell 1956: 112).

(35) *Shortening in* CVːC *syllables*

underlying	*surface*	
siːb-ha	s**i**bha	'leave it (FEM)!'
ʃuːf-ha	ʃ**u**fha	'see her!'
manadiːl-ha	manad**i**lha	'her handkerchiefs'

(ii) If MAX and MAX(μ) dominate DEP, then CVːC syllables will be eliminated by epenthesising a vowel after the coda. This occurs in Mekkan Arabic, for example (Abu-Mansour 1987).

(36) *Epenthesis with* CVːC *syllables*

underlying	*surface*	
xaːl-na	xaːl**a**na	'our maternal uncle'
saːb-hum	saːb**a**hum	'he left them'
naːj-ha	naːj**a**ha	'her flute'

(iii) If MAX(μ) and DEP dominate MAX, then CVːC syllables will be eliminated by deleting the coda (see (37)): /siːb-ha/ → [siːha].[13] To my knowledge, this never occurs.

[13] Deleting the /h/ in /siːb-ha/ would not be an option in Arabic or any other language with [pharyngeal] /h/. See §3.4.

This gap in the typology is another TMR problem. The HS explanation for this typological gap is that deleting the final consonant of a CVːC syllable requires first deleting Place, and Place deletion is not harmonically improving in this specific environment. CVːC syllables are marked because they contain too much material in the rhyme, and not because the coda has Place. The HS derivation *<siːb.ha, siːH.ha, siː.ha> can only be well-formed if its first step is harmonically improving, but the constraints against CVːC syllables, unlike CodaCond, do not ensure that.

Under the ranking in tableau (37), [siː.ha] is /siːb-ha/'s global minimum of potential for further harmonic improvement. This tableau shows that classic OT has no difficulty finding the global minimum. That is because classic OT's single pass through Gen produces a very diverse candidate set that always includes the global minimum.

(37) /siːb-ha/ → [siː.ha] *in classic OT*

/siːb-ha/	Dep	Max(μ)	*$[\mu\mu\mu]_\sigma$ *Appendix	Max
☞ a. siː.ha				*
b. siːb.ha			*!	
c. sib.ha		*!		
d. siː.ba.ha	*!			

The markedness constraints *$[\mu\mu\mu]_\sigma$ and *Appendix rule out the two possible ways of faithfully parsing [siːb], as a trimoraic syllable or as a bimoraic syllable with a non-moraic coda.

In comparison, HS's more limited Gen produces a candidate set that does not include the global minimum whenever the global minimum is at least two steps away because of gradualness. The global minimum is sometimes reached eventually, in which case classic OT and HS give identical final outputs for a given input and a given constraint hierarchy. But sometimes the global minimum is unattainable because HS gets stuck in a local minimum along the way. That is the situation in (38). The faithful form [siːb.ha] is a local minimum – there is no single step that will improve its harmony relative to this constraint hierarchy. Because debuccalisation by itself does not improve performance on the markedness constraints *[$\mu\mu\mu$] and *Appendix, the only way to get from [siːb.ha] to [siː.ha] requires first becoming less harmonic [siːH.ha] before becoming more harmonic [siː.ha]. But the Gen → Eval → Gen … loop makes that literally impossible.

(38) *Impossibility of* *<siːb.ha, siːH.ha, siː.ha>

/siːb-ha/	DEP	MAX(μ)	*[$\mu\mu\mu$]$_\sigma$ *APPENDIX	MAX	MAX[Place]
a. siːb.ha *is **more** harmonic under every ranking than*			*		
b. siːH.ha *is less harmonic than*			*		*
c. siː.ha				*	*

Obviously, the typological effects of local minima will depend on exactly which constraints are in CON and on precisely how gradualness is defined. But the point is clear from this example and the others in this article: the possibility of getting stuck in a local minimum allows HS to solve some TMR problems that challenge classic OT and its ability to always find the global minimum.

4.3 Metrically conditioned shortening

Many languages have processes of vowel shortening that are conditioned by metrical structure. In Cairene Arabic, vowels shorten in syllables that do not bear the main stress (Mitchell 1956: 111–112).

(39) *Shortening in Cairene Arabic*

	underlying	*surface*	
	qaːbil-t	q**a**ˈbilt	‘I met’
	maːsik-hum	m**a**ˈsikhum	‘holding them’
cf.	qaːbil	ˈqaːbil	‘he met’
	maːsik	ˈmaːsik	‘holding’

In Latin, vowels shorten to allow a light-heavy sequence to be parsed as a well-formed moraic trochee consisting of two light syllables (Allen 1973, Mester 1994).

(40) *Trochaic shortening in Latin*

underlying	*surface*	
putaː	(ˈput**a**)	‘think (SG)!’
woloː	(ˈwol**o**)	‘I want’

Trochaic shortening is also found in Tonkawa (Hoijer 1933, 1946, Gouskova 2003) and Fijian (Dixon 1988, Hayes 1995). English trisyllabic shortening is an instance of trochaic shortening as well (Prince 1990).

The rationale for these processes is straightforward. Shortening of unstressed long vowels is a response to the constraint WEIGHT-TO-STRESS (Prince 1990), which is violated by any syllable that is heavy yet unstressed. Trochaic shortening, as I noted, brings a light–heavy sequence into conformity with the usual quantitative requirements on trochaic feet embodied in the Iambic/Trochaic Law (I/TL) of Hayes (1995). According to I/TL, trochaic feet optimally have equal quantity, so light–light [(ˈputa)] is less marked than light–heavy *[(ˈputaː)]. For a full HS analysis of trochaic shortening, see McCarthy (forthcoming).

Deleting the coda from an unstressed heavy syllable could in principle improve performance on WEIGHT-TO-STRESS and I/TL. For example, WEIGHT-TO-STRESS would favour *[ʃaˈsijja] over faithful [ʃa**m**ˈsijja] 'parasol' in Cairene. Likewise, I/TL would favour *[(ˈputa)] over faithful [(ˈputa**t**)] 'he thinks' in Latin. Deleting the highlighted consonants in these examples turns a heavy syllable into a light one, just as vowel shortening does. Ranking MAX above WEIGHT-TO-STRESS and I/TL can account for why Cairene and Latin do not do this. But this language-particular ranking does not solve the typological problem: to my knowledge, no language satisfies WEIGHT-TO-STRESS or I/TL by deleting a consonant (except by degemination). This is another instance of the TMR problem.

With gradualness as defined in §2.2, HS has an explanation for why WEIGHT-TO-STRESS and I/TL never lead to consonant deletion. WEIGHT-TO-STRESS and I/TL are constraints on the relationship between syllable quantity and metrical structure. Obviously, neither of them says anything about the Place node, so deleting a consonant's Place node will not improve performance on either of these constraints. Consider pseudo-Cairene, where MAX is ranked below WEIGHT-TO-STRESS. The second step in the derivation *<ʃamsijja, ʃam(ˈsij)ja, ʃaN(ˈsij)ja, ʃa(ˈsij)ja> is not harmonically improving relative to WEIGHT-TO-STRESS; satisfaction of WEIGHT-TO-STRESS is not obtained until the third step. Consider also pseudo-Latin, with MAX ranked below I/TL. The second step in the derivation *<putat, (ˈputat), (ˈputaH), (ˈputa)> does not purchase better satisfaction of I/TL; that has to wait until the third step. Because consonant deletion must proceed by way of debuccalisation, and neither WEIGHT-TO-STRESS nor I/TL favours debuccalisation, these constraints acting alone cannot compel consonant deletion.

Pseudo-Cairene and pseudo-Latin are further examples of the effect of local minima in HS. In *<ʃamsijja, ʃam(ˈsij)ja, ʃaN(ˈsij)ja, ʃa(ˈsij)ja>, the form [ʃam(ˈsij)ja] is a local minimum that is distinct from the global minimum [ʃa(ˈsij)ja]. Classic OT finds the global minimum without difficulty – to its detriment, if the typological claim is correct. HS gets stuck at the local minimum, so it cannot reach the global minimum. To return to the analogy that introduced this concept, WEIGHT-TO-STRESS and I/TL are unable to push the ball over the debuccalisation bump, so the ball never makes it to the bottom of the hill.

5 Comparison with other theories

There are three other main approaches to the coda/onset asymmetry: positional faithfulness, the P-map and targeted constraints. I will briefly discuss each of them in turn, focusing on the ways in which they differ from the HS analysis presented here.

5.1 Positional faithfulness

Positional faithfulness constraints are based on the general idea that faithfulness constraints can be relativised to certain contexts (Casali 1996, 1997, Beckman 1997, 1998, Lombardi 1999, 2001 and others). At first, this looks like a promising approach to the coda/onset asymmetry. Perhaps /patka/ becomes [pa.ka] and not *[pa.ta] because /k/ is in a position of greater faithfulness. This initial optimism turns out to be unjustified. The devil is in the details.

To use a positional faithfulness constraint, we need to identify a context of greater faithfulness, and we have to say whether that context is defined on the input or the output. For instance, MAX(V:) prevents deletion of underlying long vowels, and it extends this protection to underlying long vowels that are shortened in the output, so its context must be defined on the input (Gouskova 2003, McCarthy 2005). On the other hand, Beckman (1998: ch. 3) proposes a class of IDENT$_{'\sigma}$[feature] positional faithfulness constraints that require vowels that are stressed in the output to have the same feature values as their input correspondents. In most cases, whether a syllable is stressed or not is determined by the grammar, not the lexicon, so the context for this constraint has to be defined on the output.

A positional faithfulness constraint that is intended to prevent deletion has to have its context defined on the input. There is no way to block the mapping /patka/ → *[pa.ta] with a positional faithfulness constraint that references the output, since the segment that this constraint would have to protect is missing from the output. In other words, MAX$_{\text{onset}}$ makes no sense, because a consonant's status as onset or coda is something that can only be determined by looking at the output.[14]

We therefore require a faithfulness constraint that differentiates /t/ and /k/ in /patka/. For instance, we might say that /k/ is treated more faithfully because it is prevocalic. On this view, hypothetical MAX$_{\text{prevocalic}}$ is violated whenever a consonant is deleted that is prevocalic in the input.[15]

[14] A frequent response to this argument is 'what if there is syllabification in the input?'. The problem is that OT has no way of ensuring that the input is syllabified in a particular way, given that languages differ in syllabification. This is a consequence of richness of the base, which says that the grammar rather than the lexicon is the source of all systematic differences between languages.

[15] An anonymous reviewer, citing a constraint in Burzio (2000) as precedent, suggests a similar constraint, MAX(CV), that is violated when either member of an underlying CV sequence is deleted. An unintended and unwelcome consequence of adopting this constraint is that it predicts the existence of languages where $CV_1\#V_2$ hiatus is consistently resolved by deleting V_2. According to Casali (1996), consistent

Wilson (2001) identifies the flaw in this proposal: even when a cluster is derived by syncope, it is still the first consonant in the cluster that is targeted for deletion, debuccalisation or assimilation, even though both consonants are prevocalic in underlying representation. The Cariban languages supply some nice examples. Gildea (1995) describes in detail how coda deletion, assimilation and debuccalisation processes in these languages affect consonants that have become codas by syncope. For instance, in the paradigm of the Panare verb /utu/ 'give', the final /u/ is deleted before a -CV suffix, and the preceding /t/ is debuccalised to [h] (or [ʔ] before a nasal).

(41) *Syncope and debuccalisation in Panare*

	underlying	*surface*	
	n-utu-ʧah	nu**h**ʧah	'he gave it (IMMED PAST)'
	n-utu-pəh-ʧah	nu**h**pəhʧah	'he gave it (ITER)'
	n-utu-ʧake	nu**h**ʧake	'he gave it (HIST PAST)'
	j-utu-ñe	ju**ʔ**ñe	'he's gonna give it'
cf.	n-utu-i	nutui	'he gave it (MEDIAL PAST)'
	j-utu-ŋpəh	jutuŋpəh	'(he is) giving it'

Deletion fed by syncope is illustrated by the Carib of Surinam data in (42).[16]

(42) *Syncope and deletion in Carib of Surinam* (Hoff 1968, Gildea 1995)

underlying	*surface*	
wɨː**to**-sa	wɨːsa	'I go'
epaːno**pɨ**-ko	epaːnoːko	'help him'
aj-ukuː**tɨ**-sa-ɲ	ajukuːsaɲ[17]	'he knows you'

Constraints like IDENT[Place]$_{\text{prevocalic}}$ or MAX$_{\text{prevocalic}}$ are no help in analysing these data. For instance, in /wɨːto-sa/, both /t/ and /s/ are prevocalic in the input, so there is no way of using MAX$_{\text{prevocalic}}$ to distinguish between [wiːsa] and *[wiːta]. And since MAX$_{\text{prevocalic}}$ is necessarily input-sensitive, there is no way of using the output to resolve this conundrum.

Reduction of clusters derived by syncope is entirely unproblematic under the HS system advocated here. CODACOND is not relevant until the HS derivation has progressed to the point of syncope:

deletion of V_2 is only possible when V_1 is protected by root faithfulness and V_2 is not. He reports that he has 'not found a single example of a language which generally elides V_2 at lexical word boundaries' (Casali 1996: 12).

16 The examples in (42) have optional alternate pronunciations in which the affected consonant debuccalises to [χ] instead of deleting.

17 Gildea transcribes this example with the first [u] long. I assume this is a typographical error, because the [u] is short in the underlying form and in an alternate pronunciation.

<wɨː.to.sa, wɨːt.sa, …>. At this point, the situation is exactly the same as it is in the /patka/ example: CodaCond favours debuccalisation of /t/ but not /s/, and debuccalisation is a necessary step on the way toward deletion: <wɨː.to.sa, wɨːt.sa, wɨːH.sa, wɨː.sa>.

Morpheme-initial positional faithfulness constraints offer another possible approach to the coda/onset asymmetry. Drawing on evidence from hiatus resolution, Casali (1996, 1997) proposes that morpheme-initial segments are subject to special faithfulness constraints, and Pater (2003: 25) suggests that these constraints might account for the coda/onset asymmetry. This idea could work for many commonly cited examples of the asymmetry, such as Diola Fogny. Furthermore, unlike the faithfulness constraints that refer to prevocalic position, morpheme-initial positional faithfulness would be able to deal with the Panare and Carib examples in (41) and (42).

Morpheme-initial faithfulness cannot account for all instances of the coda/onset asymmetry, however. This is shown by examples where a consonant that assimilates or deletes in coda position remains unchanged in onset position even when it is not morpheme-initial.

(i) In Syrian Arabic, coda /n/ assimilates in place to a following labial (Cowell 1964: 27): /mən beːruːt/ → [məm beːruːt] 'from Beirut'; /ʕanbar/ → [ʕambar] 'storehouse' (cf. [ʕanaːber] 'storehouses'). But onset /n/ never assimilates, even when it is not morpheme-initial: /b-jə-bni/ → [jibni], *[jibmi] 'he builds'.

(ii) In Tiberian Hebrew, /n/ (unless root-final) assimilates totally to a following consonant (Gesenius 1910: 69): /min ʃam/ → [miʃʃaːm] 'from there'; /ji-nteːn/ → [jitteːn] 'he gives' (cf. [naːθan] 'he gave'). But onset /n/ is not affected, even when it is not morpheme-initial: /ji-tne-uː/ → [jiθnuː], *[jittuː] 'they hire'.

(iii) In Akkadian, the facts are much the same as in Hebrew (Huehnergard 2005: 32, 588). Coda /n/ assimilates: /i-ndin/ → [iddin] 'he gave' (cf. [nadaːn-um] 'to give (NOM SG)'). But onset /n/ does not: /ʃakin-um/ → [ʃaknum], *[ʃakkum] 'placed (NOM SG)'.

There are also cases where the coda/onset asymmetry is observed even though *both* consonants are morpheme-initial. For instance, in Classical Arabic, a high glide assimilates totally to following /t/ in circumstances where the glide is root-initial and the /t/ is the initial (and sole) segment in an infix that is located immediately after the root-initial consonant (Wright 1896: 80): /ja-w-t-aʕid-u/ → [jattaʕidu] 'he receives a promise' (cf. [waʕada] 'he made a promise'). From this and the other evidence, it is clear that morpheme-initial faithfulness is no substitute for the HS analysis of the coda/onset asymmetry.

5.2 The P-map and related ideas

Steriade (2001, forthcoming) proposes that unfaithful mappings are constrained by perceptual similarity. When there is more than one way to satisfy markedness requirements, the optimal unfaithful mapping is the one that is most similar perceptually to the faithful candidate. Similarly, Jun (1995: 122) proposes that faithfulness 'constraints for consonantal gestures with strong acoustic cues are more highly ranked than those with weak ones'.

In the case at hand, we compare two unfaithful candidates, [pa.ka] and [pa.ta], for perceptual similarity with faithful [pat.ka]. The [t] and [k] of [pat.ka] differ in salience: [t] is less salient because its V__C context means that phonetic cues to its Place are relatively weak. In contrast, [k]'s C__V context means that those cues are more robust. The reason why /pat.ka/ becomes [pa.ka] and not *[pa.ta], then, is that [pa.ka] is simply more faithful, because relative faithfulness is a matter of perceptual similarity with the faithful candidate.

Formally, information about perceptual similarity is recorded in a data-structure called the P-map, and faithfulness constraints in universally fixed rankings are projected from the P-map. Among other things, the P-map says that a consonant is more similar to $\emptyset$ in the context V__C than in the context C__V. Two faithfulness constraints are projected from this, Max/V__C and Max/C__V, in the universally fixed ranking Max/C__V $\gg$ Max/V__C. From this it can follow that the mapping /patka/ $\rightarrow$ [pa.ka] is more faithful than the mapping /patka/ $\rightarrow$ [pa.ta] in every language.

This approach and the positional faithfulness approach are somewhat similar. In fact, the P-map can be understood as providing an answer to *why* prevocalic position evokes greater faithfulness against deletion, debuccalisation and assimilation. It is not surprising, then, that the P-map approach has the same problem as positional faithfulness does in dealing with clusters derived by syncope. The Carib candidates [wɨː.sa] and *[wɨː.ta] equally obey both Max/C__V and Max/V__C, since the contexts for these constraints are not met in the fully faithful candidate [wɨː.to.sa].

A promising line of future research is to unite HS with the study of perceptual influences on phonological mappings. The P-map's problem in classic OT is that it has only one touchstone of perceptual similarity, the fully faithful candidate. But HS's intermediate forms offer additional possibilities. For example, if Max/C__V referred to the conditions obtaining in the output of syncope, [wɨːt.sa], rather than the fully faithful candidate [wɨː.to.sa], then it would work fine. A reasonable research hypothesis is that candidates are evaluated for perceptual similarity with their immediate derivational predecessor, rather than with the underlying representation.

5.3 Targeted constraints

Standard OT constraints impose a stratified partial ordering on the entire candidate set. This means that every candidate is in the ordering (i.e. every candidate has zero or more violation marks), but some candidates tie with others. Targeted constraints, proposed by Wilson (2000, 2001), impose a partial ordering that may be non-stratified. This means that some candidates can be entirely outside the ordering, so the constraint says nothing about their relationship to other candidates. For this reason, targeted constraints do not assign violation marks; instead, they make assertions about the relative harmony of candidates.

The coda/onset asymmetry is the basis of an argument for targeted constraints in Wilson (2001). Cluster reduction is a response to the markedness constraint NoWeakCons.

(43) NoWeakCons (Wilson 2001: 160)
Let x be any candidate and α be any consonant in x that is not released by a vowel. If candidate y is exactly like x except that α has been removed, then y is more harmonic than x (i.e. $y > x$).

Whereas CodaCond favours both [pa.ka] and [pa.ta] over faithful [pat.ka], NoWeakCons favours only [pa.ka] over [pat.ka] – it says nothing about [pa.ta]. That is because [pa.ka] and [pat.ka] meet the requirement of being exactly alike except for the removal of an unreleased consonant, whereas [pa.ta] and [pat.ka] don't. In the context of the rest of targeted-constraints theory, this difference is enough to ensure that [pa.ta] can never beat [pa.ka].

Targeted-constraints theory (TCT) and HS have one important thing in common: they rely on a representation that is neither the input nor the output. In HS, this representation is the intermediate step of a derivation. In TCT, it is the candidate referred to in the 'exactly like … except' clause of (43). This point of similarity between HS and TCT is particularly clear when we consider how the two theories deal with reduction of clusters derived by syncope (§5.1). In HS, we have a derivation <wɨː.to.sa, wɨːt.sa, wɨːH.sa, wɨː.sa> with the intermediate form [wɨːt.sa]. In TCT, [wɨːt.sa] also makes an appearance; it is the 'exactly like … except' candidate: [wɨː.sa] is more harmonic than [wɨːt.sa] because [wɨː.sa] is exactly like [wɨːt.sa] except for removal of the unreleased consonant [t].

There is also an important difference between TCT and HS. A targeted markedness constraint is like a rule, because it specifies not only a prohibited configuration but also a specific way of repairing that configuration. For instance, in (43) the prohibited configuration is an unreleased consonant and the repair is deletion. In contrast, HS's markedness constraints are identical to classic OT's markedness constraints – they specify prohibited configurations but say nothing about how to fix them.

The resemblance between targeted constraints and rules might seem to abandon one of the main insights of classic OT: the same undesirable output configuration can be avoided in different ways in different languages or even in different contexts within the same language. The situation is not so dire, however, since Wilson (2001: 171–173) is careful to show that targeted NoWeakCons still allows for an analysis of languages that avoid clusters by vowel epenthesis rather than reduction. The idea is that top-ranked NoWeakCons establishes the harmonic ordering [pa.ka] ≻ [pat.ka], and then lower-ranking Max gives [pa.tə.ka] ≻ [pa.ka], [pa.ta].

Nonetheless, targeted markedness constraints do have a deficiency in comparison with standard OT markedness constraints: they cannot in general account for emergence of the unmarked effects (McCarthy & Prince 1994). Emergence of the unmarked in allomorph selection supplies an example (for others, see McCarthy 2002a: 281–282, 284–285). A widely adopted approach to allomorph selection in OT says that both allomorphs appear in underlying representation, so outputs based on either of them are equally faithful. The correct allomorph is selected by emergent markedness constraints (Burzio 1994, Mester 1994, Hargus 1995, Mascaró 1996, Tranel 1996a, b, 1998, Hargus & Tuttle 1997 and others).

For example, the nominative suffix in Korean has two allomorphs, /-i/ and /-ka/. The /-i/ allomorph follows consonants and the /-ka/ allomorph follows vowels.

(44) *Korean nominative allomorphy*

underlying	*surface*	
cip-{i, ka}	ci.bi	'house (nom)'
c^ha-{i, ka}	c^ha.ga	'car (nom)'

The standard OT markedness constraints easily do the job for Korean: Onset favours [c^ha.ga] over *[c^ha.i], and CodaCond favours [ci.bi] over *[cip.ka]. But targeted markedness constraints will not work, because they are limited to comparing forms that differ only minimally. NoWeakCons says nothing about the relative harmony of [ci.bi] and *[cip.ka], since [ci.bi] is not exactly like *[cip.ka] except that an unreleased consonant has been removed.

One of the goals of TCT is to explain why the coda/onset asymmetry cannot be disrupted by other markedness constraints. For example, since velar consonants violate *Dorsal, why don't we find languages that usually delete the first consonant in a cluster but delete the second one if it is a velar: /map-ta/ → [ma.ta], but /pat-ka/ → [pa.ta]? The answer given in Wilson (2001) is that *Dorsal could not have this effect unless it were ranked high enough to cause all velars to delete, even those that occur outside clusters. In other words, we don't find languages exhibiting this pattern of cluster simplification because any such language would completely lack velars in its inventory.

There is a flaw in this argument (McCarthy 2002a: 277–280): if Onset dominates *Dorsal, then velars will be present in the language's inventory in forms like [ka.ta] or [ta.ka], yet they will still delete in /pat-ka/ → [pa.ta]. More generally, the argument is undermined by any markedness constraint that can block deletion of /k/ in /kata/ or /taka/, but not /patka/.

It appears that the present proposal does not have this problem. For a velar to delete, it must first lose Place. *Dorsal could certainly cause that to happen. This is only a problem, however, if there exists a markedness constraint that is violated by the [H] in [Ha.ta] or [ta.Ha], but not in [mat.Ha]. I know of only two possibilities. An ad hoc constraint against intervocalic [h] appears in the McCarthy & Prince (1995) analysis of Javanese, but this turns out to be wrong because Javanese bans [h] from all onsets, not just intervocalic ones (Davis & Cho 2003; see also Parker 2001). And a constraint against intervocalic [ʔ] appears in Gabriel & Meisenburg's (forthcoming) analysis of French *h aspiré*; it is criticised and shown to be superfluous by Boersma (2007).

6 Conclusion

In this article, I have argued that harmonic serialism offers a novel account of the generalisation that simplification and assimilation of medial consonant clusters targets the would-be coda and not the would-be onset. The elements of HS that are essential to the explanation are gradualness and harmonic improvement. Gradualness is what distinguishes HS's GEN from classic OT's GEN, and harmonic improvement is a consequence of HS's basic architecture, the GEN → EVAL → GEN … loop. When combined with certain substantive assumptions about faithfulness and segmental representation, HS requires consonant deletion or Place assimilation to go by way of consonant debuccalisation. Because CODACOND favours debuccalisation in codas but not in onsets, only would-be codas can undergo deletion or assimilation in a harmonically improving fashion.

The analysis developed here and HS in general have many potential implications for our understanding of phonological phenomena. They provoke questions like the following:

(i) According to the analysis here, deletion of a coda consonant is a process of gradual attrition. Is that also true of vowel deletion?

(ii) When segments delete in template mapping or other situations, is the path also gradual?

(iii) When several segments are affected by the same process, are they changed one at a time or all at once?

(iv) Does gradualness make sense with other phonological phenomena, such as epenthesis or stress assignment?

Obviously, definitive answers to these and other questions are impossible in an article of this size. I can, however, suggest possible directions for research and call attention to any progress that has already been made.

(i) *Do vowels also delete by gradual attrition?*

One reason to think that consonant deletion is a process of gradual attrition is the similarity between debuccalisation and deletion – they occur in the same context and sometimes in the same language (see §3.4). There is a similar connection between vowel reduction and syncope: both tend to occur in syllables of low prominence. This observation suggests that vowel reduction may be a step (or two) along the path to syncope.

The details depend on exactly how we understand the process in representational and faithfulness terms. In theories that represent vowels as combinations of phonological elements (or privative features), reduction is analysed as loss of structure (e.g. Harris 1994: 107–113). Were we to assume an element theory of vowel representation within an HS analysis of reduction, then there would be one derivational step for each underlying element that is deleted. Each step would have to improve harmony, so appropriate markedness constraints on the licensing of these elements would be required. Obviously, different assumptions about representations and faithfulness would have different implications.

(ii) *What about other deletion phenomena?*

The view of deletion as gradual attrition is a good fit to coda weakening and deletion processes, and perhaps to vowel reduction and syncope. But what about other cases of deletion, particularly the loss of segments that cannot be mapped to a prosodic template? For example, the Japanese 'rustic girls' names' pattern maps a name to a bimoraic foot: [(mido)$_{\mathrm{ft}}$ɾi] → [o-(mido)$_{\mathrm{ft}}$] (Poser 1984a, b, 1990, Mester 1990). Do the [ɾ] and [i] each require at least two derivational steps to delete, like a coda consonant in Diola Fogny?

Starting with the earliest work on prosodic morphology (McCarthy 1979, Marantz 1982, McCarthy & Prince 1986), it was assumed that prosodic templates make segments pronounceable by parsing them. Segments that could not be parsed into the template, like [ɾ] and [i] in [o-(mido)$_{\mathrm{ft}}$], were not pronounced, precisely because they could not be parsed. If this traditional view of template mapping is correct, then there is no reason to expect that 'deletion' of extra-templatic segments has the same gradual character as deletion of codas in Diola Fogny. (Also see note 6 for discussion of yet another kind of deletion.)

(iii) *Do multiple instances of the same process occur sequentially or simultaneously?*[18]

If a hypothetical word of Diola Fogny has two coda consonants, does each have its own debuccalisation and deletion steps: <pak.tap.ta, pa^{h}.tap.ta, paH.taH.ta, pa.taH.ta, pa.ta.ta>? Or do all debuccalisation mappings and all deletion mappings occur simultaneously: <pak.tap.ta, paH.taH.ta, pa.ta.ta>? Although I know of no evidence bearing on this specific question about codas, there is solid evidence for the sequential account from other phenomena. In McCarthy (2007b), I argue on typological grounds that apocope, autosegmental feature spreading and metathesis can affect no more than one segment at a time. Pruitt (2008) argues, again on typological grounds, that metrical feet are assigned one at a time, and in McCarthy (forthcoming) I find further confirmation for this claim.

[18] This question has obvious connections with a prominent issue earlier in the history of generative phonology: does a rule apply simultaneously to all loci that meet its structural description (Chomsky & Halle 1968, Anderson 1974), or does it apply iteratively to one locus at a time (Howard 1972, Johnson 1972, Lightner 1972, Kenstowicz & Kisseberth 1977)?

The theoretical issue at stake here is the proper definition of gradualness. Should the definition in (2) be revised to read 'If β is a member of the set GEN(α), then no more than one *type of* unfaithful operation is required to transform α into β' or 'If β is a member of the set GEN(α), then no more than one *instance of* an unfaithful operation is required to transform α into β'? The evidence so far favours the latter version.

(iv) *Does gradualness make sense with other phonological phenomena?*

Work already discussed suggests that gradualness and harmonic improvement do indeed make sense with – and help to make sense of – phenomena like deletion, reduction, assimilation, autosegmental spreading and stress assignment. Wolf (2008) shows that HS with these premises also leads to a better understanding of phonology–morphology interactions, if the spell-out of a single morpheme is included among the operations that can constitute a single derivational step. A version of HS, OT with candidate chains (OT-CC), is applied to phonological opacity in McCarthy (2007a). Obviously, much more remains to be done, but this list covers a great deal of phonological territory.

One common phonological phenomenon that has not been mentioned so far is epenthesis. MAX[feature] constraints have DEP[feature] counterparts, so epenthesis should involve gradual, harmonically improving accretion of structure, just as deletion involves gradual, harmonically improving attrition of structure. This is certainly not a novel view of epenthesis. In the early OT literature and previously (Selkirk 1981, Broselow 1982, Piggott & Singh 1985, Itô 1986, 1989, Prince & Smolensky 1993), epenthesis is analysed as at least a two-stage process: creation of an empty timing slot followed by insertion of default features. In underspecification theory (Archangeli 1984), the default features are inserted by separate rules that apply sequentially. A plausible approach to epenthesis in HS could be built on this earlier work. There are obvious problems when epenthesis creates segments that have too much structure to be plausible defaults, but these cases are no less a problem for classic OT, rule-based underspecification theory, or markedness in general (for relevant discussion, see Lombardi 2002, 2003, Vaux 2002, Uffmann 2007).

Any novel approach to familiar phenomena is bound to raise new questions even as it answers old ones. HS is no different. Sometimes these new questions can seem like problems or even insuperable obstacles. Questions are not problems; they are opportunities for further research. HS offers many such opportunities.

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