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Abstract Many languages respect the generalization that some or all unstressed vowels are deleted. This generalization proves elusive in classic Optimality Theory, however. The source of the problem is classic OT's parallel evaluation, which requires that the effects of stress assignment and syncope be optimized together. This article argues for a version of OT called Harmonic Serialism, in which the effects of stress assignment and syncope can and must be evaluated sequentially. The results are potentially applicable to other domains where process interaction is best understood in derivational terms.

Keywords Harmonic Serialism · Optimality Theory · Stress · Syncope

1 Introduction

Deletion of unstressed vowels is a common phonological process. For example, Macushi Carib has left-to-right iambic stress with lengthening of stressed vowels and deletion or reduction of unstressed vowels:

(1) Macushi Carib (Hawkins 1950: 87)

Underlying	Surface	
wanamari	wˌnaːmˈriː	‘mirror’
u-wanamari-rɨ	ˌwaːnˌmaːrˈrɨː	‘my mirror’

I will refer to this phenomenon as metrically-conditioned syncope (MCS), since properties of metrical structure determine which vowels delete.

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Extant approaches to MCS in rule-based phonology and Optimality Theory are very different from one another. In rule-based phonology, MCS is analyzed by ordering metrical-structure assignment before deletion of unstressed vowels. In classic OT (Prince and Smolensky 1993/2004), the effects of metrical-structure assignment and syncope are evaluated together, in parallel.

In this paper, I will present an approach to MCS that is situated in a version of OT called Harmonic Serialism (HS). HS combines classic OT's core assumptions with a type of serial derivation. I will support this approach by arguing that MCS is better analyzed as serial rather than simultaneous optimization of the effects of metrical structure assignment and deletion.

The paper begins (Sect. 2) with essential background material: a short summary of the relevant properties of HS. It then continues (Sect. 3) with an overview of what HS has to say about MCS. This is followed (Sect. 4) by a case study to illustrate how this approach works. Section 5 describes the typological implications of this theory, while Sect. 6 compares it with alternatives. Section 7 extends the theory to two phenomena that are abstractly similar to MCS, metrically-conditioned shortening and metrically-conditioned lengthening. Section 8 summarizes.

2 About Harmonic Serialism

HS is a derivational version of OT. It was originally proposed by Prince and Smolensky (1993/2004), who discuss it briefly before putting it aside. The *locus classicus* is the following quotation:

> "Universal grammar must provide a function Gen that admits the candidates to be evaluated. In the discussion in chapter 2 we have entertained two different conceptions of Gen. The first, closer to standard generative theory, is based on serial or derivational processing: 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. This is then evaluated; and the process continues with the output so determined. In this serial version of grammar, the theory of rules is narrowly circumscribed, but it is inaccurate to think of it as trivial. There are constraints inherent in the limitation to a single operation and in the requirement that each individual operation in the sequence improve Harmony." (Prince and Smolensky 1993/2004: 94–95)

In other words, HS's GEN is limited to making one change at a time and EVAL selects the optimal member of this limited set of possibilities. The output of EVAL becomes another input to GEN, and the derivation continues until the point of convergence, when the latest output of EVAL is identical with the latest input to GEN.[1]

Prince and Smolensky's sketch of HS is silent about various details that need to be spelled out before we can use HS to analyze data. Furthermore, in the course of

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[1] For further discussion of Harmonic Serialism, see McCarthy (2000, 2002: 159–163, 2007a, 2007b, to appear). Related ideas include Harmonic Phonology (Goldsmith 1990: 319ff, 335–336; 1993), Constraint-Ranked Derivation (Black 1993), Constraint Cumulation Theory (Norton 2003), and the OT syllable parser in Tesar (1995).

exposition it will prove useful to have names for some of the properties of this model. To these ends, I will summarize the proposals and formulations in McCarthy (2007a), where a particular version of HS is worked out.

GEN "is allowed to make a certain single modification to the input". I will refer to this property of HS as *gradualness*. Gradualness imposes a limit on how much each step in an HS derivation can differ from the step that precedes it. There are several imaginable ways of defining this limit, and faithfulness theory offers a good option: GEN can add violations of only one *basic faithfulness constraint* at a time (McCarthy 2007a: 61–62, 77–79). The basic faithfulness constraints are in a one-to-one relationship with the basic operations in GEN, such as deletion (MAX), insertion (DEP), and changing a feature value (IDENT). Assigning a stress also violates a basic faithfulness constraint, which I will refer to (somewhat inaccurately) as IDENT(stress).[2] A single step of an HS derivation may violate one or more non-basic faithfulness constraints, though never more than one basic faithfulness constraint.

For instance, the HS derivation <tap, ta.pi, ta.bi> is properly gradual.[3] It adds a DEP violation in the first step by epenthesizing [i]. Concomitant resyllabification of [p] is allowed because it does not bring any additional violations of basic faithfulness constraints.[4] An IDENT(voice) violation is added in the next step. This step shows why we need to distinguish the basic faithfulness constraints: voicing of [p] to [b] violates only one basic faithfulness constraint, IDENT(voice), whereas it may also violate other non-basic faithfulness constraints, such as IDENT-ONSET(voice) (Lombardi 1995/2001).

Because of the gradualness requirement, *<tap, ta.bi> is not a possible HS derivation. It is impossible because it introduces violations of two different basic faithfulness constraints, DEP and IDENT(voice), in a single step.

Ideas similar to gradualness antedate OT. It harks back to proposed limitations on how much a single application of a phonological rule can do, as in Archangeli and Pulleyblank's (1994) parametric rule system or Prince's (1983) Move-x. The basic faithfulness constraints and the corresponding operations in GEN are analogous to the elementary transformations mentioned in Chomsky's (1965: 147) definition of a grammatical transformation: "a Boolean condition on Analyzeability and a sequence of elementary transformations drawn from a base set including substitutions, deletions, and adjunctions."

Defining gradualness brings up the *multiple application problem* that first emerged in the early 1970's. This problem arises whenever a single phonological process

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[2] Although discussions of stress in OT rarely mention faithfulness constraints, the existence of IDENT(stress) or something like it follows from a basic point of OT logic: any property that a language can use contrastively must have a corresponding faithfulness constraint, since otherwise markedness constraints would always obliterate the contrast (cf. footnote 4). Stress is predictable in some languages, but it is not predictable in all languages, so a stress faithfulness constraint is needed in universal CON.

[3] Notation: Angled brackets < > are used for HS derivations, parentheses mark metrical feet, and vertical bars surround prosodic words. When necessary, syllable boundaries are indicated by a period/full stop. I will often ignore the difference between primary and secondary stress.

[4] Syllabification of tautomorphemic sequences is never contrastive within a language (Blevins 1995: 221; Clements 1986: 318; Hayes 1989: 260; McCarthy 2003b: 60–62). In OT, this means that there cannot be any faithfulness constraints that are protective of syllabification. (Though cf. Elfner 2006 for a different view, and see Elfner 2006; Bermúdez-Otero 2001; and Campos-Astorkiza 2004 on moraic faithfulness.)

could apply at multiple loci in a form. Is the process applied simultaneously at every locus where its structural description is met (Anderson 1974; Chomsky and Halle 1968), or does it apply iteratively to one locus at a time (Howard 1972; Johnson 1972; Kenstowicz and Kisseberth 1977; Lightner 1972)? A similar question arises in HS: can all IDENT(stress) violations be added simultaneously, as in hypothetical <pa.ta.ka.ma.sa.fa, (ˈpa.ta)(ˈka.ma)(ˈsa.fa)>, or must they be added one by one, as in <pa.ta.ka.ma.sa.fa, (ˈpa.ta)ka.ma.sa.fa, (ˈpa.ta)(ˈka.ma)sa.fa, . . . >? In the analysis in Sect. 4.3, I opt for allowing GEN to simultaneously add multiple violations of a single basic faithfulness constraint, so derivations like <pa.ta.ka.ma.sa.fa, (ˈpa.ta)(ˈka.ma)(ˈsa.fa)> are allowed. I do this for an expository reason: it allows the analysis of stress in HS to maximally resemble the much more familiar analysis of stress in parallel OT. But in Sect. 4.4.2 I will argue for an iterative approach.

Another consequence of the basic HS architecture is *harmonic improvement*—"the requirement that each individual operation in the sequence improve Harmony". On every pass through GEN and EVAL, the form chosen by EVAL must be more harmonic than the input to GEN, or else identical to it (cf. Moreton 2003 on classic OT). If the form chosen is more harmonic than the input, then it becomes the input to another pass through GEN and EVAL. If it is identical to the input, then further harmonic improvement is not possible and the derivation terminates (i.e., it "converges").

Harmonic improvement in HS is best explained with an example. Suppose we have a language with the following constraint hierarchy:

(2) A hypothetical constraint hierarchy
NO-CODA $\gg$ $*VC_{\text{voiceless}}V$ $\gg$ DEP, IDENT(voice)

Under this hierarchy, the only gradual and harmonically improving derivations from the input /kad/ are <kad> and <kad, ka.di>. The singleton derivation <kad> is trivially gradual and harmonically improving. The longer derivation <kad, ka.di> is harmonically improving because [ka.di] satisfies NO-CODA $\gg$ DEP better than [kad] does, and it is gradual because epenthesis of [i] incurs a violation of a single basic faithfulness constraint. In contrast, *<kad, kat> is not a possible derivation because it does not improve harmony relative to this hierarchy: [kat] introduces a violation of IDENT(voice) with no compensating improvement on any higher-ranking constraint.

Harmonic improvement in HS resembles a core principle of the theory of Harmonic Phonology (Goldsmith 1990: 319ff, 335–336; 1993): rules apply only when they improve harmony (which is defined in that theory as conformity with phonotactics). On the other hand, it is quite different from stratal versions of OT, which posit different grammars for different strata (Ito and Mester 2003; Kiparsky 2000; Rubach 1997; and many others). HS uses the same grammar on each pass through Gen and Eval, so harmonic improvement is always relative to the same grammar. In stratal OT, the harmony requirements of different strata can be, and usually are, inconsistent.

Since harmonic improvement is so central to HS, we require a device similar to the classic OT violation tableau to check whether a putative derivation does in fact improve harmony relative to a proposed constraint hierarchy. In (3) I give a *harmonic improvement tableau*, which shows that each step in a derivation is more harmonic than its predecessor.

(3) Harmonic improvement tableau for <pap, pa.pi, pa.bi>

/pap/	No-Coda	*VC$_{\text{voiceless}}$V	Dep	Ident(voice)
a. pap *is less harmonic than*	1!			
b. pa.pi *is less harmonic than*		1!	1	
c. pa.bi			1	1

In tableau (3) and elsewhere, I show faithfulness violations relative to the original underlying representation, not to the input of the latest pass through Gen. That assumption is not very important in this article, but it is required for the proper application of HS to phonological opacity in McCarthy (2007a). Tableau (3) also employs a couple of conventions that I will use throughout: integers rather than asterisks to count violations, and the exclamation point to signal a violation whose removal improves harmony.

Tableau (3) certifies that <pap, pa.pi, pa.bi> is harmonically improving under the given constraint hierarchy. The form [pa.pi] in (3b) improves over the harmony of [pap] in (3a) because [pa.bi] eliminates [pap]'s No-Coda violation without adding violations of any constraints ranked higher than No-Coda. (There are none.) Likewise, [pa.bi] in (3c) improves over the harmony of [pa.pi] in (3b) because [pa.bi] eliminates [pa.pi]'s violation of *VC$_{\text{voiceless}}$V without adding violations of any constraints ranked higher than *VC$_{\text{voiceless}}$V.

As I just noted, harmonic improvement follows from the nature of Eval and its role in HS. These elements of the HS architecture are also the source of the property called *local optimality* in McCarthy (2007a: 61–62). After each pass through Eval, the result is the most harmonic candidate from the restricted candidate set provided by HS's Gen. It is locally optimal within that restricted set, though it may not be the ultimate output of the grammar.

Stress nicely illustrates local optimality. Assume a language with trochaic feet and the following constraint hierarchy:

(4) Another hypothetical constraint hierarchy
Align-L(word, foot) $\gg$ Align-R(word, foot) $\gg$ Ident(stress)

Align-L(word, foot) is violated by any word-initial syllable that is not also foot-initial. Given this hierarchy, both <pa.ta.ka, (ˈpa.ta)ka> and <pa.ta.ka, pa(ˈta.ka)> are harmonically improving, since they improve performance on Align-L(word, foot) and Align-R(word, foot), respectively, at the expense of introducing a violation of low-ranking Ident(stress). Under local optimality, [(ˈpa.ta)ka] and [pa(ˈta.ka)] compete as different ways of improving harmony. Since Align-L(word, foot) ranks higher, [(ˈpa.ta)ka] is locally optimal. This means that <pa.ta.ka, (ˈpa.ta)ka> is a possible derivation in this language but *<pa.ta.ka, pa(ˈta.ka)> is not.

Analyzing linguistic data in HS requires attention to the derivational path as well as the ultimate output. If getting from /A/ to [B] requires several steps, but there is no route from /A/ to [B] that is gradual, harmonically improving, and locally optimal at each step, then [B] is not a possible output for /A/. This means that some logically possible input-output mappings can be analyzed in parallel OT but not HS when identical constraint sets are employed. There is evidence from language typology that this is a desirable property of HS (see McCarthy 2007a, 2007b, 2008; and cf. Bíró 2006).

A final point. HS is not an alternative to OT; rather, it is a variant implementation of OT's basic ideas, just as classic OT is another implementation. Harmonic improvement and local optimality are not some special principles of HS; they are intrinsic to EVAL and hence common to all versions of OT. Gradualness is the only property that is unique to HS. Although I have kept the name "Harmonic Serialism" for historical reasons, it might be more accurate to refer to HS as serial or gradual OT, distinguishing it in the only important respect from classic or parallel OT.

3 Stress-syncope interaction

This section develops two main results about how assignment of metrical structure interacts with metrically-conditioned syncope in HS. One result is *forced serialism*: metrical-structure assignment and syncope cannot be simultaneous. Rather, they must occur at different steps in an HS derivation. The other result is *intrinsic ordering*: metrical-structure assignment and metrically-conditioned syncope must occur in that order. These results will prove particularly important when we turn to language typology in Sects. 5 and 6.1, since they limit the range of possible variation between languages.

3.1 Forced serialism

Assignment of metrical structure and MCS cannot occur simultaneously in HS. This follows from gradualness: assignment of metrical structure and syncope violate different basic faithfulness constraints, so they must occur in different steps of the derivation. Hypothetical derivations like <pa.ta.ka, (ˈpa.ta)ka, (ˈpat)ka> or <pa.ta.ka, pat.ka, (ˈpat)ka> are gradual, but *<pa.ta.ka, (ˈpat)ka> is not.

The forced serial interaction of metrical-structure assignment and MCS is clearly different from classic OT, where assignment of metrical structure and syncope must be simultaneous. It is also different from stratal OT. Stratal OT could model a serial derivation with stress before syncope, but because each stratum is a classic OT grammar, it is also possible to get simultaneous assignment of metrical structure and syncope within a single stratum. Thus, stratal OT permits but does not force serial interaction of stress and syncope.

Gradualness has another consequence for the analysis of syncope in HS: it rules out analyses where stress is first assigned, and then the stressed vowel deletes with concomitant stress shift, usually to the other syllable in the foot. Syncope and (re)assignment of stress violate different basic faithfulness constraints, so they cannot be accomplished simultaneously with HS's GEN. Since analyses with syncope and shift have been important in the development of metrical theory, I digress briefly to explain why we should be content to eliminate them.

Bedouin Arabic presents one of the best cases for stress shift after syncope (Al-Mozainy 1981; Al-Mozainy et al. 1985; Hayes 1995: 228ff; Irshied and Kenstowicz

1984; Kenstowicz 1983; Kenstowicz and Abdul-Karim 1980). A typical derivation is shown in (5). Stress is assigned to the antepenult by the Latin stress rule, the stressed syllable deletes, and stress is automatically reassigned to the other syllable in the foot. If the Latin stress rule were instead applied after syncope, the predicted result would be *[(ˈʔin)ksarat].

(5) Syncope and stress shift in Bedouin Arabic

Underlying	/ʔin-kasar-at/	‘it (fem.) was broken’
Stress	ʔin(ˈkasa)rat	
Syncope with shift	ʔin(ˈksa)rat	

This analysis has serious problems, not the least of which is that it offers no rationale for deletion of the stressed vowel. Bedouin Arabic is reanalyzed without stressed vowel deletion or stress shift in McCarthy (2003b, 2007a). The main idea is that the basic stress pattern is iambic [ʔin(kaˈsa)rat], and deletion of the unstressed member of the iambic foot is an instance of MCS. Syncope in Bedouin Arabic is no mystery; in fact, it is much like syncope in Aguaruna and other languages discussed later in this article.[5]

Prince (1983: 93–95) and Hayes (1995: 42fn) discuss cases of accent shift after syncope in pitch accent systems like Japanese (Bennett [Archangeli] 1981) or Indo-European (Halle and Vergnaud 1987). Arguably, this behavior has nothing to do with metrical structure. Rather, it is a case of a tone persisting under deletion—-that is, a tonal autosegment remains floating and reassociates to a nearby syllable when its original host is deleted (Goldsmith 1976). Stress cannot float because it is a phonological relation rather than a phonological object, like a tone. In metrical theory, stress is syntagmatic, not paradigmatic.

Finally, hiatus resolution processes can sometimes produce the illusion of stress shift. For instance, Hutchinson (1974) proposes a rule of stress shift in South Texas Spanish to account for examples like /benˈdra iˈnes/ → [benˌdriˈnes] *vendrá Inez* ‘Inez will come’. Although this made sense at the time, it no longer seems necessary once we recognize that (i) hiatus is resolved by merging two syllables (including actual segmental coalescence in some cases (Baković 2007)) and (ii) stress and accent are properties of syllables or moras. The situation in Classical Greek appears to be similar. End of digression.

Because of gradualness, metrical-structure assignment and MCS must occur in *some* order. In the next section, I will argue that they must occur in a *specific* order: metrical-structure assignment must precede MCS. In the rule-ordering literature of the 1970’s, a pair of rules that could only apply in a particular order were said to be *intrinsically* ordered, and I have adopted that term here.

3.2 Intrinsic ordering

It might seem self-evident—no more than a simple point of logic—that syncope conditioned by metrical structure has to follow assignment of metrical structure. Some-

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[5] Tiberian Hebrew is another language that has been analyzed with syncope and concomitant stress shift (Churchyard 1999; McCarthy 1979a, 1981; Prince 1975).

times, that which seems obvious is not. Actually, MCS is intrinsically ordered after metrical-structure assignment only if certain constraints are excluded from Con. I will discuss two such constraints and show why they should be rejected on independent grounds. At the end of this section, I will explain what these constraints have in common, in order to clarify the implications of the intrinsic-ordering claim for the general structure of Con.

An example of a constraint that must be excluded is Parse-Syllable, under the following definition:

(6) Parse-Syllable (to be rejected) (after McCarthy and Prince 1993a: 91)
Assign one violation mark for every syllable that is not dominated by some foot.

Under this definition of Parse-Syllable, syncope will improve harmony even in representations that have no foot structure whatsoever. The following harmonic improvement tableau illustrates:

(7) <pa.ta.ka, pat.ka, (ˈpat)ka> with Parse-Syllable as defined in (6)

	/pataka/	Parse-Syll	Ident(stress)	Max
a.	pa.ta.ka *is less harmonic than*	3!		
b.	pat.ka *is less harmonic than*	2!		1
c.	(ˈpat)ka	1	1	1

This is a case of MCS, since a constraint on metrical structure, Parse-Syllable, crucially favors [pat.ka] over [pa.ta.ka]. But here, MCS *precedes* metrical-structure assignment, thereby contradicting my claim about intrinsic ordering.

As it happens, there are sound reasons to doubt the validity of the constraint Parse-Syllable under the definition in (6). The main problem with this definition is that it is not situated in some larger theory of prosodic parsing. A better alternative to Parse-Syllable comes from prosodic theory, specifically the Strict Layer Hypothesis of Selkirk (1984). The Strict Layer Hypothesis is a claim about the prosodic hierarchy (Nespor and Vogel 1986; Selkirk 1980): a constituent of type X^n can immediately dominate only constituents of type X^{n-1}. Inter alia, this means that a prosodic word node cannot immediately dominate a syllable node. In OT, the inviolable Strict Layer Hypothesis has been replaced by a family of violable constraints Exhaustivity(X^n) (abbreviated Exh(X^n)) (Ito and Mester 1992/2003; Selkirk 1995):

(8) Exhaustivity(X^n)
Assign one violation mark for every constituent of type X^m that is immediately dominated by a constituent of type X^n, if $m < n - 1$.

For example, [|(ˈpa.ta)ka|] incurs one violation of Exhaustivity(word) because the syllable [ka] is immediately dominated by the word node (indicated by | |), skipping the foot level.

Unlike Parse-Syllable, Exhaustivity(word) cannot compel syncope prior to the assignment of metrical structure above the level of the syllable. Before the metrical word node has been introduced, the form [pa.ta.ka] vacuously satisfies Exhaustivity(word). This means that no derivation beginning with *<pa.ta.ka, pat.ka, ...> can be harmonically improving under this constraint system:

(9) *<pa.ta.ka, pat.ka, ...> with Exhaustivity(word)

/pataka/	Exh(wd)	Ident(stress)	Max
a. pa.ta.ka *is **more** harmonic than*			
b. pat.ka			1

Observe that [pat.ka] has a proper superset of [pa.ta.ka]'s violation marks, so [pa.ta.ka] harmonically bounds [pat.ka] within this small constraint set. This means, as is obvious from inspection, that no ranking of these constraints can produce harmonic improvement in *<pa.ta.ka, pat.ka, ...>. For Exhaustivity(word) to serve as the impetus to syncope, the prosodic word node must be present. Therefore, syncope to satisfy Exhaustivity(word) cannot precede assignment of higher-level metrical structure. The claim about intrinsic ordering is vindicated.

Syncope in unstressed syllables presents another potential challenge to the claim about intrinsic ordering. Suppose that vowel reduction (and, *a fortiori*, deletion) involves loss of a vowel's place features. Vowel reduction and deletion in unstressed syllables might then be attributed to the following markedness constraint:

(10) *V-Place$_{\text{unstressed}}$ (to be rejected)
Assign one violation mark for every place-bearing vowel that is not in the head syllable of some metrical foot.

The choice between reduction and deletion can be determined by the ranking of Ident(V-place) and Max. For the languages discussed here, Ident(V-place) is higher ranked, since there is deletion rather than reduction.

Under the definition in (10), *V-Place$_{\text{unstressed}}$ (abbreviated *V-Pl$_{\text{uns}}$) can compel syncope prior to metrical-structure assignment. The harmonic improvement tableau (11) shows that the derivation <pa.ta.ka, pat.ka, (ˈpat)ka> is harmonically improving because it eliminates one *V-Place$_{\text{unstressed}}$ violation in its first step.

(11) <pa.ta.ka, pat.ka, (ˈpat)ka> with*V-Place$_{\text{unstressed}}$

/pataka/	*V-Pl$_{\text{uns}}$	Ident(stress)	Max
a. pa.ta.ka *is less harmonic than*	3!		
b. pat.ka *is less harmonic than*	2!		1
c. (ˈpat)ka	1	1	1

If this is right, then metrical-structure assignment is not intrinsically ordered before MCS.

The problem with *V-Place$_{\text{unstressed}}$ is that it is not situated in some larger theory of prosodic licensing of segmental features. Superior alternatives to *V-Place$_{\text{unstressed}}$ are discussed by Crosswhite (1999), de Lacy (2002, 2006), Gouskova (2003), Kenstowicz (1996), and Prince and Smolensky (1993/2004), among others. The overall thrust of this work is that syllables in metrically weak positions disfavor vowels with high intrinsic prominence.[6] Unlike *V-Place$_{\text{unstressed}}$, these constraints do not define metrical weakness as mere absence of stress. Instead, they define metrical weakness positively, by specifying the metrically weak positions that are poor licensers of unreduced vowels. Typically, at least two such positions are recognized: (i) the non-head syllable of a disyllabic foot, and (ii) a syllable that is immediately dominated by the word node. Throughout most of this article, I will use a single licensing constraint, *V-Place$_{\text{weak}}$ (abbreviated *V-Pl$_{\text{weak}}$), which is violated by a place-bearing vowel in either of the metrically weak positions (i) and (ii). Later, in Sect. 5, I will discuss the need to distinguish between (i) and (ii) (for which also see de Lacy 2006: 225ff).

Substituting *V-Place$_{\text{weak}}$ for *V-Place$_{\text{unstressed}}$, as I've done in (12), means that *<pa.ta.ka, pat.ka, . . . > is not harmonically improving. The reason for this change is that *V-Place$_{\text{weak}}$ is vacuously satisfied by [pa.ta.ka], which has no metrical structure and therefore no metrically weak positions.

(12) *<pa.ta.ka, pat.ka, . . . > with *V-Place$_{\text{weak}}$

	/pataka/	*V-Pl$_{\text{weak}}$	Ident(stress)	Max
a.	pa.ta.ka *is **more** harmonic than*			
b.	pat.ka			1

Observe once again that the first form in this HS derivation harmonically bounds the second form within the scope of these constraints. This means that the derivation is impossible no matter how these constraints are ranked. (Of course, some other markedness constraint might break this harmonic bounding, but that is not the point of the example.) Syncope to satisfy *V-Place$_{\text{weak}}$ cannot precede assignment of metrical structure.

To sum up, I have argued that metrical-structure assignment is intrinsically ordered before MCS only if the constraints Parse-Syllable as defined in (6) and *V-Place$_{\text{unstressed}}$ as defined in (10) are excluded from OT's universal constraint component Con. Clearly, it would be useful to know what other imaginable constraints must be banned from Con for the intrinsic ordering claim to go through. To that end, we should ask what Parse-Syllable and *V-Place$_{\text{unstressed}}$ have in common.

The problem with Parse-Syllable is that it conflates two distinct conditions: a syllable that is immediately dominated by a word node and a syllable that is not yet organized into any higher-level prosodic structure. Similarly, *V-Place$_{\text{unstressed}}$ conflates syllables parsed as foot or word adjuncts with syllables that have not been

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[6] Here, I have defined "high intrinsic prominence" as "having V-Place", but this expedient is obviously not a necessary property of the analysis.

parsed at all. The problematic constraints make these conflations because they crucially refer to the complete absence of some unit of higher-level structure (a foot or a foot-head). I am not aware of any other proposed constraints that have this property. In any case, the claim about intrinsic ordering depends on the non-existence of such constraints.

3.3 The metrical imperative

If there is no constraint with the effect of PARSE-SYLLABLE in (7), then what is the imperative to impose foot structure? In HS terms, how does the derivation <pa.ta.ka, (ˈpa.ta)ka> improve harmony? Here, I briefly digress from the main argument to address these questions. The answers come from prosodic hierarchy theory. Morphosyntactic words are parsed into prosodic words, and every prosodic word must contain at least one foot.

Morphosyntactic words are parsed into prosodic words to satisfy grammar-prosody interface constraints like Prince and Smolensky's (1993/2004: 51–55) LX ≈ PR or Selkirk's (1995) WDCON. These constraints have the effect of requiring every morphosyntactic word to be parsed as a prosodic word.

The introduction of a prosodic word node entails the simultaneous introduction of feet. The reason: GEN cannot create a prosodic word that contains no feet. This follows from the more or less standard assumption that every prosodic word has a head foot.[7] The only reason to doubt this assumption is the existence of languages like Japanese, which has a pitch accent system rather than stress. But there is also abundant evidence for foot structure in Japanese (Ito 1990; Ito et al. 1996; Ito and Mester 1992/2003; Poser 1990). Therefore, the absence of stress cannot entail the absence of feet.

In HS terms, this means that any step in a derivation that introduces the word level of constituency must also introduce the foot level: <pa.ta.ka, |(ˈpa.ta)ka|, . . . >, but never *<pa.ta.ka, |pa.ta.ka|, |(ˈpa.ta)ka|, . . . >. This is entirely consistent with the gradualness requirement, because assigning word constituency brings with it no violations of any basic faithfulness constraints, besides those incurred by concomitant foot assignment.[8] The following harmonic improvement tableau shows the ranking conditions necessary for <pa.ta.ka, |(ˈpa.ta)ka|, . . . > to be a possible HS derivation:

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[7] The claim that prosodic word headedness is a condition on GEN naturally raises the question of whether WDCON is also a condition on GEN. (If so, as Junko Ito points out, every derivation would necessarily begin with the word and foot levels already present, so the intrinsic ordering of stress before syncope would follow trivially.) Violable WDCON is essential to Selkirk's (1995) theory of clitics. Specifically, it is violated in languages with "internal" clitics, which are parsed into the same prosodic word as their hosts: |word + clitic|. For instance, Arabic pronominal clitics are internal, since they form a single stress domain with the host word.

[8] There is a long history behind the observation that parsing into words has no faithfulness cost. Chomsky and Halle (1968: 366ff) imply that word-juncture symbols # are absent from lexical entries; Pyle (1972: 516) says this outright. The nearest thing to a counterexample known to me is Hayes' (1982: 264) suggestion that *góbbledy#gook* and *búdgeri#gar* have a lexically specified internal word juncture to account for the main-stressed nonfinal dactyl and internal stressless tense [iː]. Alternatively, they are just exceptions like *cátamaran* and *kátydid*.

(13) Harmonic improvement in <pa.ta.ka, |(ˈpa.ta)ka|, . . . >

	/pataka/	WdCon	Ident(stress)	Exh(wd)
a.	pa.ta.ka *is less harmonic than*	1!		
b.	|(ˈpa.ta)ka|		1	1

With this brief digression into the theory of prosodic structure, I have shown that the definition of Parse-Syllable in (6) is not needed to ensure that syllables are parsed into feet. The interface constraint WdCon/Lx ≈ Pr compels the presence of a prosodic word node, while prosodic word headedness and Exhaustivity(word) do the rest.

3.4 Summary

In HS, violations of different basic faithfulness constraints require different derivational steps, and each step must improve harmonically over the one before it. When the derivation includes both assignment of metrical structure and syncope conditioned by that structure, the only possible order is stress before syncope. This intrinsic ordering follows from HS's basic architecture and independently motivated properties of Con. As we will see in Sects. 5 and 6.1, the intrinsic ordering of stress before syncope establishes a close linkage between stress typology and MCS typology in HS.

4 Case study: Aguaruna

4.1 Introduction

Aguaruna is a Jivaroan language spoken in Peru. Native speakers apparently now prefer the name Awajún [ɑʋɑhʊ́n̪] (Asangkay Sejekam 2006). Except where noted, all data and generalizations come from Payne (1990). Alderete (2001: 295ff) gives an OT analysis of Aguaruna's pitch-accent system, including some discussion of metrical structure and syncope.

In general, syncope affects odd-numbered syllables counting from the left, as in the following examples. (To help in identifying the vowels that delete, they are in boldface in the underlying representations).

(14) Syncope in Aguaruna

Underlying	Surface	
itʃinak**a**	itʃinak	‘pot’
itʃin**a**kan**a**	itʃinkan	‘pot (acc.)’
itʃin**a**kaŋ**u**min**a**	itʃinkaŋmin	‘your pot (acc.)’
itʃin**a**kaŋ**u**minak**ɨ**	itʃinkaŋminak	‘only your pot (acc.)’

There are some complications—for instance, initial vowels never delete and final vowels always delete—but the basic pattern is one where odd-numbered syllables are targeted for deletion.

This pattern of syncope makes sense as MCS in a language with left-to-right iambic feet. Since HS analyzes MCS as stress assignment, then syncope, the easiest way to understand Aguaruna's syncope pattern is to look at a language with iambic feet and no syncope. One such language is Axininca Campa (McCarthy and Prince 1993b; Payne et al. 1982). Axininca Campa parses a word into iambic feet from left to right, except that it has a trochee finally in words ending in an even-parity sequence of light syllables (see (15)). (The trochee is required in disyllables but may be omitted in polysyllables.)

(15) Iambic parse in Axininca Campa

a.	(hiˈno)ki	'up (by the river)'
	(iˌʧʰi)(kaˈki)na	'he cut me'
b.	(kiˈmi)(ˌtaka)	'perhaps'
	(hoˈti)(ˌtana)	'he let me in'
	(ˈmato)	'moth'

Applying exactly the same parse to the underlying forms in (14) yields the results in (16):

(16) Aguaruna iambic parse
(iˈʧi)(ˈnak**a**)
(iˈʧi)(n**a**ˈka)n**a**
(iˈʧi)(n**a**ˈka)(ŋ**u**ˈmi)n**a**
(iˈʧi)(n**a**ˈka)(ŋ**u**ˈmi)(ˈnak**ɨ**)

The vowels that delete are boldfaced in (16). They are exactly the non-initial syllables that the iambic parse has left unstressed.

The rest of this section is devoted to explaining how the HS analysis imposes an iambic parse and then deletes unstressed vowels. That events happen in this order is guaranteed by the intrinsic ordering results in Sect. 3: MCS does not improve harmony until metrical structure has been assigned.

4.2 Evidence for iambic feet

Stress is not actually reported for Aguaruna. Thus, any evidence for iambic feet is necessarily somewhat indirect. This section reviews that evidence.

The most compelling independent argument for iambic feet in Aguaruna comes from the system of tonal accent. Aguaruna has a tonal accent that is partly lexical, partly morphological. It is in general independent of the iambic parse, except that the iambic parse is needed to account for the direction of tone shift when an accented vowel is deleted. (On why tones can shift but stresses cannot, see 3.1.) Alderete (2001: 298ff) demonstrates in detail how this works.

For example, the root /uŋuʃí/ in (17) has a lexical tone on its final vowel. Since this vowel is in an odd-parity syllable, it deletes and its accent is displaced elsewhere. In (17a), it shifts to the head syllable of the foot that contains it. In (17b), however, accent cannot shift onto the head syllable of the foot because that syllable is also word-final in the output. This extratonality effect reflects a general pattern in the language.

(17) Tone shift

	Underlying	Iambic parse	Surface	
a.	uŋuʃínumina	(uˈŋu)(ʃíˈnu)(ˈmina)	uŋuʃnúmin	‘tree-species (acc.)’
b.	uŋuʃínumi	(uˈŋu)(ʃíˈnu)mi	uŋúʃnum	‘tree-species’

Without the iambic parse, it would be necessary to stipulate the preferred rightward direction of tone shift. With the iambic parse, it follows naturally.

The fact that stress is not reported for Aguaruna is not too surprising for various reasons. Cross-linguistically, stress is an abstract property with various phonetic correlates, principally amplitude, pitch, and duration. In Aguaruna, though, these properties have all been usurped by other aspects of the phonology. Pitch is under the control of the tonal accent system. So is amplitude, since the amplitude peak is on the syllable containing the tonal accent (Payne 1990: 165–166). And since vowel length is phonemic, duration also has another function.

In fact, one could argue that syncope *is* the realization of Aguaruna’s stress system. Much like Macushi Carib in (1), Aguaruna rather aggressively eliminates the nonheads of feet as an indirect way of marking their heads. This is MCS *par excellence*.

4.3 Analysis

The analysis of syncope in Aguaruna requires a two-step derivation, stress assignment followed by syncope. We have already seen that this is an intrinsic ordering relationship because the constraint that compels deletion of unstressed vowels, *V-PLACE$_{\text{weak}}$, is vacuously satisfied until prosodic word and foot structure has been assigned. Furthermore, we know that the two steps in this derivation must be accomplished with a single, internally consistent constraint ranking because HS posits only a single grammar (unlike stratal OT). The goal of this section is to determine what that ranking is. This section will focus on the core phenomenon: alternating syncope in medial syllables. Section 4.4 presents some refinements.

An HS analysis of Aguaruna’s covertly iambic stress step will be almost identical to a classic OT analysis of an overtly iambic language like Axininca Campa. The basic techniques for analyzing iambic stress in OT are known from McCarthy and Prince (1993b: 159ff), Kager (1999: 148ff), and much other work. I will not dwell on them too much here.

Every step in an HS derivation must improve harmonically over its predecessor. Every derivation in Aguaruna starts with a step where the metrical parse is first introduced: <i.ʧi.na.ka.ŋu.mi.na, |(iˈʧi)(naˈka)(ŋuˈmi)na|, . . . >. For this step to be harmonically improving, WdCon must dominate Ident(stress) and Exhaustivity(word) (cf. (13)):

(18) Harmonic improvement in metrical parsing

	/iʧinakaŋumina/	WdCon	Ident(stress)	Exh(wd)
a.	i.ʧi.na.ka.ŋu.mi.na *is less harmonic than*	1!		
b.	|(iˈʧi)(naˈka)(ŋuˈmi)na|		3	1

Recall that Exhaustivity(word) is vacuously satisfied when no prosodic word is present. That is why there are no violation marks next to (18a) in the Exhaustivity(word) column.

Every step in an HS derivation must also be locally optimal in the sense that it is the most harmonic of the candidates allowed by gradualness. For instance, the trochaic parse in *<i.ʧi.na.ka.ŋu.mi.na, |(ˈi.ʧi)(ˈna.ka)(ˈŋu.mi)na|, . . .> is also harmonically improving in its first step, since it too better satisfies WdCon. But we know that the trochaic parse cannot be correct, since it assigns stress to syllables—[na] and [ŋu]—that should undergo syncope at the next step. Under local optimality, the iambic and trochaic parses compete to be the more harmonic way of building feet. HS makes this choice in exactly the same way that classic OT does. Furthermore, the choice is made in Aguaruna's covertly iambic parse in exactly the same way that it is made in an overtly iambic language like Axininca Campa: the iambic parse wins because FootForm = Iamb (abbreviated Ft = I) dominates FootForm = Trochee (Ft = T). (FootForm = Iamb is violated by any foot whose head syllable is not final; Foot-Form = Trochee is its mirror image.) The ranking argument is given in tableau (19).

(19) FootForm = Iamb ≫ FootForm = Trochee
Input: /iʧinakaŋumina/

	Candidates for stress step	Ft = I	WdCon	Ft = T	Exh(wd)	Id(str)
a. →	|(iˈʧi)(naˈka)(ŋuˈmi)na|			3	1	3
b.	|(ˈi.ʧi)(ˈna.ka)(ˈŋu.mi)na|	3 **W**		**L**	1	3
c.	i.ʧi.na.ka.ŋu.mi.na		1 **W**	**L**	**L**	**L**

Tableau (19) is in the comparative format introduced by Prince (2002). The integers are just the counts of asterisks, as above. The **W**s and **L**s are unique to this format. **W**s and **L**s appear only in loser rows, where they indicate how each loser performs relative to the winner on each constraint. A **W** means that the constraint favors the winner over the loser. For instance, FootForm = Iamb favors the winner (19a) over the loser (19b) because the loser has three violations of this constraint and the winner has none. **L**s mark the opposite favoring relation. For instance, FootForm = Trochee favors the losers in (19b) and (19c) over the winner, since only the winner violates this constraint. If a cell in a loser row contains neither **W** nor **L**, such as the WdCon cell in row (19b), then the loser ties with the winner on that constraint. One advantage of comparative tableaux is that they present constraint ranking relations very transparently: in a properly ranked comparative tableau, every **L** has a **W** somewhere to its left across a solid line. That is, every constraint that favors the loser must be dominated by some constraint that favors the winner. (This is the Cancellation/Domination Lemma of Prince and Smolensky 1993/2004: 153–154.)

In the winning candidate (19a), the final syllable is left unfooted, so it is not stressed: [|(iˈʧi)(naˈka)(ŋuˈmi)**na**|], not *[|(iˈʧi)(naˈka)(ŋuˈmi)(ˈ**na**)|]. This inference is based on the observation that word-final vowels act like other unstressed vowels in consistently undergoing syncope.

There are two possible explanations for why [na] remains unfooted and unstressed in [|(iˈʧi)(naˈka)(ŋuˈmi)**na**|]: Foot-Binarity or Non-Finality. Foot-Binarity (abbreviated Ft-Bin) is violated by monomoraic feet like [(ˈna)]. As we will see in 4.4.2, Foot-Binarity is ranked too low to have the desired effect. Therefore, Non-Finality must be the responsible constraint. Since Aguaruna stresses word-final heavy syllables (see 4.4.4), the specific constraint required is Non-Finality(ˈσ_{light}) (abbreviated NF(ˈσ_{L})), which is violated by word-final stressed light syllables. It is roughly equivalent to final mora extrametricality in the pre-OT literature.

Tableau (20) shows how Non-Finality(ˈσ_{light}) is ranked. In the comparison between (20a) and (20b), Non-Finality(ˈσ_{light}) favors leaving the final syllable unfooted. Therefore, it must dominate Exhaustivity(word). The (20a)/(20c) comparison shows that leaving additional syllables unfooted is not allowed. Two constraints disfavor iambic footing, FootForm = Trochee and Ident(stress), so these constraints must be ranked below Exhaustivity(word).

(20) Non-Finality(ˈσ_{light}) ≫ Exh(word) ≫ Foot = Trochee, Id(stress)
Input: /iʧinakaŋumina/

	Candidates for stress step	NF(ˈσ_{L})	Exh(wd)	Ft = T	Id(str)
a. →	|(iˈʧi)(naˈka)(ŋuˈmi)na|		1	3	3
b.	|(iˈʧi)(naˈka)(ŋuˈmi)(ˈna)|	1 **W**	**L**	3	4 **W**
c.	|(iˈʧi)nakaŋumina|		5 **W**	1 **L**	1 **L**

Non-Finality(ˈσ_{light}) also accounts for the left-to-right parse in Aguaruna, Axininca Campa, and other iambic languages. As tableau (21) shows, anything other than left-to-right parsing will produce final stress or a final trochee in odd-parity sequences of light syllables (McCarthy and Prince 1993b: 162–163). (None of the other constraints discussed so far discriminates among these candidates, so they are omitted from this tableau.)

(21) Non-Finality(ˈσ_{light}) and direction of foot parsing
Input: /iʧinakaŋumina/

	Candidates for stress step	Ft = I	Ft = T		NF(ˈσ_{L})
a. →	|(iˈʧi)(naˈka)(ŋuˈmi)na|	3			
b.	|(iˈʧi)(naˈka)ŋu(miˈna)|		3		1 **W**
c.	|i(ʧiˈna)(kaˈŋu)(miˈna)|		3		1 **W**
d.	|(iˈʧi)(naˈka)ŋu(ˈmina)|	1 **W**	2 **L**		
e.	|i(ʧiˈna)(kaˈŋu)(ˈmina)|	1 **W**	2 **L**		

Non-Finality(ˈσ_{light}) is shown off to the right of the tableau because its ranking with respect to the other two constraints cannot be determined from these candidate comparisons. In other words, it is a tie-breaker. In a comparative tableau, a constraint in a tie-breaking role can be identified by its Ws with no Ls in the same rows. Since no constraint in this tableau favors the losers (21b) and (21c), Non-Finality(ˈσ_{light}) can be ranked anywhere and still correctly favor the winner.

Although Non-Finality(ˈσ_{light}) cannot be ranked on the basis of the odd-parity input in (21), the analysis of even-parity inputs shows that it dominates FootForm = Iamb and confirms that it dominates Exhaustivity(word). Iambic languages have various ways of dealing with Non-Finality in even-parity words. Macushi Carib (1) simply violates it. Hixkaryana (Derbyshire 1985; Hayes 1995: 205ff; Kager 1999: 148ff) leaves the last two syllables unfooted, violating Exhaustivity(word). Axininca Campa has the third option available: violating FootForm = Iamb by parsing the last foot as a trochee. The fact that Aguaruna systematically deletes final vowels suggests that it too parses the last foot as a trochee, leaving the final syllable unstressed. All three of these typological options are reflected by the candidates in tableau (22):

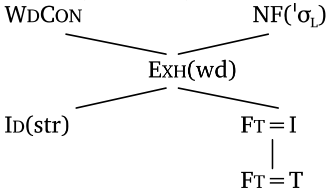
(22) Non-Finality(ˈσ_{light}) ≫ Exhaustivity(word) ≫ FootForm = Iamb
Input: /iʧinakaŋuminakɨ/

	Candidates for stress step	NF(ˈσ_L)	Exh(wd)	Ft = I	Ft = T
a. →	|(iˈʧi)(naˈka)(ŋuˈmi)(ˈnakɨ)|			1	3
b.	|(iˈʧi)(naˈka)(ŋuˈmi)nakɨ|		2 **W**	**L**	3
c.	|(iˈʧi)(naˈka)(ŋuˈmi)(naˈkɨ)|	1 **W**		**L**	4 **W**

Although FootForm = Trochee also favors the winner over (22c), this constraint cannot be decisive, since we have already established in (19) that it is ranked below FootForm = Iamb.

To sum up the discussion so far, we have seen how the stress step in an Aguaruna MCS derivation works. Stress improves harmony because of undominated WdCon, and an Axininca Campa-style iambic parse is locally optimal because of several constraint rankings that are known to occur in overtly iambic stress systems: iambic feet predominate because FootForm = Iamb dominates FootForm = Trochee; odd-parity words are parsed with a word-final unfooted syllable because Non-Finality(ˈσ_{light}) dominates Exhaustivity(word); and even-parity words end in a trochee because Non-Finality(ˈσ_{light}) and Exhaustivity(word) dominate FootForm = Iamb. The rankings can be represented in a Hasse diagram:

(23) Ranking summary I



Now that we have a grasp on what happens at the stress step in the HS derivation, we can begin to look at the syncope step. As I have emphasized throughout, a single constraint ranking must correctly determine harmonic improvement and local optimality at the stress step and at the syncope step. Thus, the ranking results established so far must be consistent with any additional rankings needed to accomplish syncope.

I assume that *V-Place$_{\text{weak}}$ is the markedness constraint that crucially favors syncope. Even before looking at the role of this constraint in syncope, we need to determine its ranking with the respect to the constraints already discussed, since it is important that it not interfere with the results already achieved.

*V-Place$_{\text{weak}}$ favors stressed vowels over unstressed ones. In this respect, it is similar to Exhaustivity(word), which favors foot assignment and therefore indirectly favors stress assignment. Because of this similarity, it is not surprising to find that the same constraints that dominate Exhaustivity(word), WdCon and Non-Finality(ˈσ$_{\text{light}}$), must also dominate *V-Place$_{\text{weak}}$:

(24) WdCon, Non-Finality(ˈσ$_{\text{light}}$) ≫ *V-Place$_{\text{weak}}$
Input: /iʧinakaŋumina/

	Candidates for stress step	WdCon	NF(ˈσ$_{\text{L}}$)	*V-Pl$_{\text{weak}}$
a. →	|(iˈʧi)(naˈka)(ŋuˈmi)na|			4
b.	i.ʧi.na.ka.ŋu.mi.na	1 **W**		**L**
c.	|(iˈʧi)(naˈka)(ŋuˈmi)(ˈna)|		1 **W**	3 **L**

Candidate (24b) vacuously satisfies *V-Place$_{\text{weak}}$, for the reasons given in 3.2. Therefore, creating metrical structure also creates opportunities for *V-Place$_{\text{weak}}$ to be violated. And (24c) eliminates one more unstressed vowel than the winner does. These rankings are necessary, then, so that (24b) and (24c) will not interfere with the correct choice of the winner at the stress step.

Since *V-Place$_{\text{weak}}$ is able to compel syncope of unstressed vowels, it has to dominate Max, as shown in tableau (25). The output of the stress step appears immediately above the tableau, with boldface highlighting the vowels that delete.

(25) *V-Place$_{\text{weak}}$ ≫ Max
Result of stress step: [|(iˈʧi)(n**a**ˈka)(ŋ**u**ˈmi)n**a**|] (from (19) and (21))

	Candidates for syncope step	*V-Plc$_{\text{weak}}$	Max
a. →	|(iˈʧin)(ˈkaŋ)(ˈmin)|	1	3
b.	|(iˈʧi)(naˈka)(ŋuˈmi)na|	4 **W**	**L**

Tableau (25) presents a straightforward comparison between candidates with and without syncope. Candidate (25b) is identical to the output of the stress step; if it were optimal, then we would have convergence and the derivation would terminate. Candidate (25a) offers superior performance on *V-Place$_{\text{weak}}$ because it has eliminated three unstressed vowels. It does this at the expense of violating Max, because of the deletions. It has final stress, but on a heavy syllable rather than a light one, so Non-Finality(ˈσ$_{\text{light}}$) remains unviolated.

Tableau (25) raises several questions that need to be addressed before we go on to look at additional examples. One has to do with the resyllabification of consonants that were formerly onsets, such as the two [n]s and the [ŋ] in (25a). There is a good deal of evidence that these consonants are indeed parsed as codas in the output (see

6.1.3). Resyllabification can occur in the same derivational step as syncope because gradualness is defined in terms of violations of basic faithfulness constraints (Sect. 2). It is generally understood that resyllabification of a consonant is cost-free in faithfulness terms. Therefore, (25a) is consistent with the properties of HS assumed here.

Another question evoked by (25) has to do with an imaginable candidate like *[ǀ(ˈitʃ)(ˈnak)(ˈŋum)nalǀ]. This candidate has been obtained by deleting the stressed vowels and simultaneously shifting their stresses to the unstressed vowels in the same foot. As we already saw in 3.1, syncope with simultaneous stress shift is inconsistent with gradualness. Therefore, this putative candidate is in fact no candidate at all—it is not even produced by GEN from the stress-step output [ǀ(iˈʧi)(naˈka)(ŋuˈmi)nalǀ].

On the other hand, *[ǀ(iˈʧi)nakŋumnalǀ] is a legitimate candidate. It is the result of deleting the stressed vowels and their stresses together. (Since stress is a relation on a head, the relation disappears when the head does.) This sort of deletion *is* consistent with gradualness, but it is ruled out in this case because it does not improve harmony. Because it has four violations of *V-PLACE$_{\text{weak}}$, *[ǀ(iˈʧi)nakŋumnalǀ] is no better than the loser in (25b). On top of that, it also has two violations of MAX, whereas (25b) has none. Therefore, (25b) is a harmonic bound on *[ǀ(iˈʧi)nakŋumnalǀ] within this set of constraints.

Tableau (25) showed the effect of syncope on an odd-parity input. With even-parity inputs, the erstwhile antepenult becomes a monomoraic foot: [ǀ(iˈʧin)(ˈkaŋ)**(ˈmi)**(ˈnak)ǀ]. Therefore, *V-PLACE$_{\text{weak}}$ must also dominate FOOT-BINARITY:

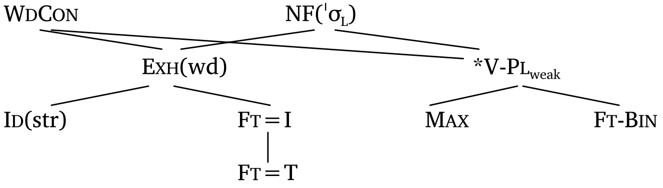
(26) Syncope with even-parity input
Result of stress step: [ǀ(iˈʧi)(n**a**ˈka)(ŋ**u**ˈmi)(ˈnak**ɨ**)ǀ] (from (22))

	Candidates for syncope step	*V-PL$_{\text{weak}}$	MAX	FT-BIN
a. →	ǀ(iˈʧin)(ˈkaŋ)(ˈmi)(ˈnak)ǀ	1	3	1
b.	ǀ(iˈʧi)(naˈka)(ŋuˈmi)(ˈnakɨ)ǀ	4 **W**	**L**	**L**

With *V-PLACE$_{\text{weak}}$ ranked above FOOT-BINARITY, there is a danger of perfectly satisfying the former at the stress step while flagrantly violating the latter. That danger is exemplified by a candidate that stresses every syllable:, *[ǀ(ˈi)(ˈʧi)(ˈna)(ˈka)(ˈŋu)(ˈmi)(ˈna)(ˈkɨ)ǀ]. In 4.4.2, I will explain why that candidate cannot win in HS, though it could win in classic OT.

These additional ranking results are included in the following diagram:

(27) Ranking summary II



All of the rankings added since (23) can be identified by the fact that they have *V-PLACE$_{\text{weak}}$ as one of their vertices. The constraints ranked above *V-PLACE$_{\text{weak}}$ are necessary because *V-PLACE$_{\text{weak}}$ is vacuously satisfied when there is no metrical structure (WDCON) and because final light syllables in odd-parity words are unstressed and unfooted (Non-Finality(ˈσ_{light})). The constraints below *V-Place$_{\text{weak}}$ are there so *V-Place$_{\text{weak}}$ can compel syncope (Max) even if the result is a monomoraic foot (Foot-Binarity).

I began the discussion of Aguaruna with the list of examples in (14) that illustrate the pattern of syncope. In (28), those examples are repeated, but with the optimal forms at the stress and syncope steps included as well. (I continue the practice of boldfacing vowels at the stress step if they will be deleted at the syncope step, and I omit the prosodic word indicators | | since their presence has already been sufficiently discussed.)

(28) Data in (14) analyzed

Underlying	Stress step	Syncope step
itʃinaka	(iˈtʃi)(ˈnak**a**)	(iˈtʃi)(ˈnak)
itʃinakana	(iˈtʃi)(n**a**ˈka)n**a**	(iˈtʃin)(ˈkan)
itʃinakaŋumina	(iˈtʃi)(n**a**ˈka)(ŋ**u**ˈmi)n**a**	(iˈtʃin)(ˈkaŋ)(ˈmin)
itʃinakaŋuminakɨ	(iˈtʃi)(n**a**ˈka)(ŋ**u**ˈmi)(ˈnak**ɨ**)	(iˈtʃin)(ˈkaŋ)(ˈmi)(ˈnak)

Glosses: ‘pot’; ‘pot (acc.)’; ‘your pot (acc.)’; ‘only your pot (acc.)’

These examples show that the analysis does what was promised: it accounts for which vowels undergo syncope. The grammar in (27) produces both the stress and syncope steps, assigning iambic feet in the former and deleting unstressed vowels in the latter. The assignment of iambic feet leads to temporary violations of *V-Place$_{\text{weak}}$, but most of these violations are eliminated as soon as gradualness permits.

This pretty much completes the analysis of Aguaruna, except for a few details that are discussed in the next section. The central idea of this analysis is that the pattern of syncope in Aguaruna makes sense if syncope is preceded by stress assignment. The stress pattern that is required covertly in Aguaruna is identical to the stress pattern that is observed overtly in Axininca Campa and other languages. The ordering of stress assignment before syncope is intrinsic—it follows from the basic principles of HS (gradualness and harmonic improvement) and an assumption about Con (*V-Place$_{\text{weak}}$ cannot be violated until stress assignment has identified some syllables as weak).

Section 5 shows what HS predicts about MCS in general, and Sect. 6 shows why other approaches to MCS are unsatisfactory. But first, we will look at a few other interesting details of the analysis of Aguaruna.

4.4 Further details

4.4.1 Initial immunity

Initial syllables, even though they are unstressed, never undergo syncope. The obvious move is to invoke a positional faithfulness constraint. Beckman (1997, 1998) and Casali (1996, 1997) have argued that word-, root-, or morpheme-initial position is a locus of special faithfulness. In Aguaruna, the vowel that resists deletion is word- and root-initial.

Though a positional faithfulness approach is certainly possible, it misses something. There is one other situation in the language when syncope unexpectedly fails, in words consisting of just two light syllables, such as [nuka] ‘leaf’. The grammar proposed here will parse /nuka/ as [|(ˈnuka)|] at the stress step; we would then expect the final vowel to delete, yielding *[|(ˈnuk)|]. This fact requires an explanation.

I speculate that the immunity of initial vowels and of the final vowel in [nuka] have the same explanation: a requirement that the head foot contain two syllables. This constraint, FOOT-BINARITY-σ_{head}, prohibits deletion of the final vowel in [|(ˈnuka)|] because this word’s sole foot must also be the head foot. FOOT-BINARITY-σ_{head} also prohibits deletion of the initial vowel in [|(iˈʧin)(ˈkaŋ)(ˈmi)(ˈnak)|], if we assume that the leftmost foot is also the head foot. FOOT-BINARITY-σ_{head} will accomplish both of these aims if it is ranked above *V-PLACE$_{weak}$.

4.4.2 Iterative stress assignment

The discussion of gradualness in Sect. 2 left an issue unresolved, and now I will address it. The general question is this: if *in* is the input to HS’s GEN and *out* is the output, how different can they be? The core assumption is that the differences between *in* and *out* involve no more than one basic faithfulness constraint. The unresolved question is whether the differences can involve more than one violation of the *same* basic faithfulness constraint.

In Sect. 2, I noted that this question recalls an important issue in phonology of the 1970’s: does a rule apply simultaneously to all segments that meet its structural description, or does it apply iteratively to one segment at a time? In gradualness terms, simultaneous application is analogous to allowing *in* and *out* to differ by more than one violation of the same basic faithfulness constraint, while iterative application is analogous to limiting the difference to a single violation of a basic faithfulness constraint. The analysis of Aguaruna in 4.3 took the simultaneous approach—not for any empirical reason, but because classic OT takes the simultaneous approach as well, and it seemed desirable for expository reasons to minimize this potential difference between HS and classic OT so as to focus the discussion on the main point, stress-syncope interaction.

There is evidence in Aguaruna, however, that the iterative approach is actually the right one. The argument below complements Pruitt’s (2008) much broader range of evidence and results about iterative stress in HS.

The argument is based on a ranking paradox that comes to light when additional candidates and constraints are considered. We saw in (26) that *V-PLACE$_{weak}$ has to dominate FOOT-BINARITY. The argument was based on the observation that syncope produces monomoraic feet in examples like [|(iˈʧin)(ˈkaŋ)**(ˈmi)**(ˈnak)|]. The paradox is that this ranking produces the wrong result—in fact, it produces an absurd result—at the stress step, since it causes every non-final syllable to form a foot of its own (see (29)). (The final foot in (29b) is a trochee because of the ranking in (22).)

(29) Unwanted consequence of *V-PLACE$_{weak}$ ≫ FOOT-BINARITY
Input: /iʧinakaŋuminakɨ/

<table>
<tr><th></th><th>Candidates for stress step</th><th>*V-PL$_{weak}$</th><th>FT-BIN</th></tr>
<tr><td>a. →</td><td>|(iˈʧi)(naˈka)(ŋuˈmi)(ˈnakɨ)|</td><td>4</td><td></td></tr>
<tr><td>b.</td><td>|(ˈi)(ˈʧi)(ˈna)(ˈka)(ˈŋu)(ˈmi)(ˈnakɨ)|</td><td>1 L</td><td>6 W</td></tr>
</table>

In a comparative tableau, the sign of a ranking paradox is an undominated **L**. This situation cannot be salvaged with, say, a constraint against stress clashes, since syncope often produces stress clashes in Aguaruna. For instance, the winner in (26) has four stressed syllables in a row and the loser has none.

The problem in (29) arises because of the assumption that all stresses are assigned at once. In an HS system where only one stress can be assigned on each pass through Gen and Eval, there is no way for (29b) to be optimal. The following tableau shows this:[9]

(30) One stress at a time
Input: /itʃinakaŋuminakɨ/

	Candidates for stress step	*V-Pl$_{weak}$	Ft-Bin
a. →	|(iˈtʃi)nakaŋuminakɨ|	7	
b.	|(ˈi)tʃinakaŋuminakɨ|	7	1 **W**

Another iambic foot is assigned on the next pass through Gen and Eval:

(31) Another stress assigned
Input: /itʃinakaŋuminakɨ/

	Candidates for stress step	*V-Pl$_{weak}$	Ft-Bin
a. →	|(iˈtʃi)(naˈka)ŋuminakɨ|	6	
b.	|(iˈtʃi)(ˈna)kaŋuminakɨ|	6	1 **W**

And so on. In both tableaux, the losing candidates are harmonically bounded within this small constraint set. Indeed, it is likely that they are harmonically bounded *tout court*, since there is no reason to assume that universal grammar supplies any constraints that favor feet consisting of a single light syllable when parsing non-final light-light sequences.

The assumption that gradualness limits derivations to adding exactly one basic faithfulness violation at a time solves a ranking paradox in the grammar of Aguaruna. It also resolves a typological problem that equally affects classic OT. As far as we know, no language allows the parse in (29b). But the constraint interaction in (29) is completely typical of classic OT, and (equivalents of) the constraints *V-Place$_{weak}$ and Foot-Binarity can be found in Prince and Smolensky (1993/2004). Thus, even classic OT is predicting that some language could have (29b) as a winner. It is interesting that the shift to HS both discloses and solves this typological problem.

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[9] To get foot assignment to start at the left, it is necessary to assume that Align-L(foot, word) dominates Align-R(foot, word) (though these constraints lose their most invidious characteristics under the iterative regime of Pruitt 2008). The candidate [|(iˈtʃi)nakaŋuminakɨ|] is therefore locally optimal in comparison with alternatives like *[|i(tʃiˈna)kaŋuminakɨ|], *[|itʃinakaŋu(miˈna)kɨ|], etc.

4.4.3 Apocope

In 4.3, I analyzed apocope in Aguaruna as a consequence of (i) not stressing final CV because of Non-Finality(ˈσ_{light}) and (ii) satisfying *V-Place$_{weak}$. Alderete (2001) instead attributes apocope to the constraint Final-C, which is violated by any prosodic word ending in a vowel (Gafos 1998; McCarthy 1993; McCarthy and Prince 1994; Piggott 1999; Wiese 2001). Although the differences between these two analyses are not very important, the Final-C alternative is useful for illustrating how it is sometimes possible for a stressed vowel to delete.

Final-C's definition refers to the prosodic word, so it is vacuously satisfied before higher-level metrical structure has been created. Thus, apocope mediated by Final-C, like syncope mediated by *V-Place$_{weak}$, is intrinsically ordered after stress assignment. Suppose for the purpose of discussion that Non-Finality is not active in Aguaruna, so odd- and even-parity words emerge from the stress step with final stress: [|(iˈʧi)(naˈka)(ŋuˈmi)(ˈ**na**)|], [|(iˈʧi)(naˈka)(ŋuˈmi)(naˈ**kɨ**)|]. As I noted in 4.3, HS's Gen will produce candidates where a stressed vowel is deleted (and its stress relation disappears), so [|(iˈʧi)(naˈka)(ŋuˈmin)|] and [|(iˈʧi)(naˈka)(ŋuˈmi)nak|] are valid candidates and consistent with gradualness. They are also harmonically improving if Final-C dominates Max. Final-C has no care for whether a word-final vowel is stressed or not; all it says is that a prosodic word ending in a consonant is more harmonic than a prosodic word ending in a vowel. Deleting a stressed vowel will not improve harmony relative to *V-Place$_{weak}$, but it certainly can improve harmony relative to Final-C. This is nothing but a banal truth about OT: harmony is always determined relative to a constraint hierarchy.

4.4.4 Syllable weight

The examples that we have examined so far consist entirely of light syllables at the point when stress is assigned. Aguaruna also has heavy syllables. As (32) shows, Aguaruna treats CVː and CVV heavy syllables in exactly the same way as any overtly iambic stress system does: they can occupy a whole foot like [(ˈʃaː)], or they can occupy the right branch of a disyllabic iamb like [(kaˈwau)], but they cannot occupy the left branch, which is limited to light syllables. Because they are always stressed, they satisfy *V-Place$_{weak}$, so they never undergo syncope.

(32) Aguaruna words with CVː or CVV

	Underlying	Stress step	Syncope step
a.	kawau	(kaˈwau)	(kaˈwau)
b.	ʃaːŋumina	(ˈʃaː)(ŋ**u**ˈmi)n**a**	(ˈʃaːŋ)(ˈmin)
c.	aːŋkɨasahaĩ	(ˈaːŋ)(ˈkɨa)(s**a**ˈhaĩ)	(ˈaːŋ)(ˈkɨas)(ˈhaĩ)
d.	aɰɻaɨkiamahaĩ	(aˈɰɻaɨ)(ˈkia)(m**a**ˈhaĩ)	(aˈɰɻaɨ)(ˈkiam)(ˈhaĩ)
e.	aːŋkɨasanuma	(ˈaːŋ)(ˈkɨa)(s**a**ˈnu)m**a**	(ˈaːŋ)(ˈkɨas)(ˈnum)

Glosses: 'parrot', 'your corn (acc.)', 'with the palm spear', 'with the catfish', 'in the palm spear'

Examples like (32a), (32c), and (32d) show that word-final light-heavy sequences are stressed iambically, not trochaically: *[(ˈaːŋ)(ˈkɨa) (ˈsahaĩ)]. In this respect, they differ from word-final light-light sequences (see (22)). This difference follows from the formulation of Non-Finality(ˈσ_{light}): it bans final (ˈCV), but not final (ˈCVː), (ˈCVV), or (ˈCVC).

Payne's (1990) data include only one morpheme that ends in a consonant in underlying representation, the disyllabic suffix /-ʃakam/ 'also'. The syllable [kam] is evidently heavy, judging from the following example:

(33) Heaviness of final CVC

Underlying	Stress step	Syncope step
nukaʃakam	(nuˈka)(ʃ**a**ˈkam)	(nuˈkaʃ)(ˈkam)

Gloss: 'also a leaf'

This suffix is also the locus of the only reported inconsistency in the choice of which vowel to syncopate: /utʃinaʃakam/ 'to the child also' is pronounced as [utʃintʃakam], which conforms to expectations, or [utʃinaʃkam], which does not (Payne 1990: 174–175). The [utʃinaʃkam] variant may indicate that this suffix is in the process of being reanalyzed as /-ʃkam/.

Underlying representations in Aguaruna also contain intervocalic homorganic NC clusters. The examples in (34) show that the syllables preceding these clusters must be light, since these words are parsed just like the similar-length CVCV… words in (14).

(34) Aguaruna words with homorganic NC clusters

Underlying	Stress step	Syncope step
tʃaŋkina	(tʃaŋˈki)n**a**	(tʃaŋˈkin)
tʃaŋkinana	(tʃaŋˈki)(ˈnan**a**)	(tʃaŋˈki)(ˈnan)
tʃaŋkinaŋumina	(tʃaŋˈki)(n**a**ˈŋu)(ˈmin**a**)	(tʃaŋˈkin)(ˈŋu)(ˈmin)
tʃaŋkinaŋuminakɨ	(tʃaŋˈki)(n**a**ˈŋu)(m**i**ˈna)k**ɨ**	(tʃaŋˈkin)(ˈŋum)(ˈnak)

Glosses: 'basket'; 'basket (acc.)'; 'your basket (acc.)'; 'only your basket (acc.)'

The weightlessness of homorganic NC clusters is consistent with another fact about them: they alternate with single consonants when syncope puts them in coda position. Thus, the /mp/ sequence in underlying /taku**mp**ɨŋumɨka/ 'your macaw (focus)' is realized as just [m] in the surface form [ta.ku**m**.ŋu.mɨk]. In this respect and in their non-contribution to weight, the homorganic NC clusters are acting more like single segments than like true clusters.

5 Typological implications

5.1 Introduction

In classic OT, any analysis of a particular language implies claims about language typology. The same goes for the HS version of OT. Because syncope follows stress assignment (Sect. 3.2), we can base our typology of MCS on established results in the known typology of stress. For every possible stress pattern, there is also a possible pattern of syncope that deletes those vowels that are left unstressed. Deletion may be limited to a well-defined subset of unstressed vowels, or it may be prohibited in certain contexts, such as initially, but in general there should be a fairly close connection between observed stress patterns and observed syncope patterns. Because stress assignment is intrinsically ordered before MCS, we do not need to consider more complex scenarios where some or all of the MCS process is simultaneous with or precedes stress assignment. (More about this in 6.1.2.) And because of gradualness, we do not need to consider the possibility of deleting stressed vowels with concomitant stress shift (3.1).

Ideally, the investigation of MCS typology would start with a typology of stress systems that is based on a specific theory of the stress constraints in Con. I will skip that step because it is an entirely different research project. Instead, I will take a shortcut: start with stress patterns that are well-attested in languages without MCS. Precisely because these patterns are well-attested, any adequate theory of stress systems has to generate them. There are three basic stress patterns to consider: iambs, which are probably always left to right; left-to-right trochees; and right-to-left trochees. We will look at each of them in turn.

5.2 Iambs

The iambic stress pattern is schematized in (35). Although odd-parity words are generally treated the same, iambic languages differ in how they deal with even-parity words.[10] The choice among the three options in (35a)–(35c) is determined by the ranking of Non-Finality(ˈσ), Exhaustivity(word), and FootForm = Iamb, as in (22). Creek is an example of an overtly iambic language that follows pattern (35a) (Haas 1977). Axininca Campa has (35b) and (35c) in free variation (McCarthy and Prince 1993b; Payne et al. 1982), while pattern (35c) is the norm in Negev Bedouin Arabic and Hixkaryana (Derbyshire 1985; Hayes 1995; Kager 1999).

(35) Iambic stress schematically

Parity	Stress step	
Odd		(paˈta)(kaˈba)(daˈga)na
Even	a.	(paˈta)(kaˈba)(daˈga) *or*
	b.	(paˈta)(kaˈba)(ˈdaga) *or*
	c.	(paˈta)(kaˈba)daga

In a language with the ranking $*$V-Place$_{\text{weak}}$ $\gg$ Max, stress is intrinsically ordered before syncope, as we have seen. If the stress step imposes the iambic pattern in (35), then exactly the unstressed vowels in (35) will be potential targets for deletion. Three such languages are Aguaruna, Macushi Carib (Hawkins 1950; Kager 1997), and Potawatomi (Anderson 1992: 148fn; Hockett 1948). All three languages agree in deleting medial unstressed syllables like *ka*. They differ in how they treat initial and final syllables.

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[10] Strictly speaking, the relevant distinction is not between odd- and even-parity words but between odd- and even-parity word-final sequences of light syllables. I say "words" to avoid repeating this cumbersome phrase.

In Aguaruna, as we have seen, initial syllables are immune because of FOOT-BINARITY$_{\text{head}}$. This constraint is not active in the other two languages, nor are constraints against initial clusters, so syncope affects unstressed initial syllables.

The treatment of final syllables depends on whether the stress constraints select the (35a), (35b), or (35c) pattern in even-parity words. Macushi Carib deletes the penult and preserves the ultima: <u.wa.na.ma.ri.rɨ, (**u**ˈwa)(n**a**ˈma)(r**i**ˈrɨ), (ˈwaː)(nˈmaː)(rˈrɨː)> ‘my mirror’.[11] This is expected if Macushi Carib follows the (35a) pattern, violating NON-FINALITY(ˈσ) in order to satisfy EXHAUSTIVITY(word) and FOOT-FORM = IAMB. Above, Aguaruna was analyzed with the (35b) pattern. Potawatomi may follow the (35c) pattern; Hockett’s description is not entirely clear.

In sum, there is a very good match between the predictions about syncope that follow from (35) and the patterns that are actually observed.

5.3 Left-to-right trochees

The left-to-right trochaic stress pattern is schematized in (36). This pattern is well attested; some of the best-known examples are Cairene Arabic (McCarthy 1979b) and Pintupi (Hayes 1995: 62–64).

(36) Left-to-right trochaic stress schematically

Parity	Stress step
Odd	(ˈpata)(ˈkaba)(ˈdaga)na
Even	(ˈpata)(ˈkaba)(ˈdaga)

Tonkawa illustrates MCS in a language with the quantity-sensitive version of (36) (Gouskova 2003: 122ff; Hoijer 1933, 1946):[12]

(37) Tonkawa syncope

Input to stress step	Stress step	Syncope step
ja.ka.poʔ	(ˈja.k**a**)(ˈpoʔ)	(ˈjak)(ˈpoʔ)
ke.ja.ma.xoʔ	(ˈke.**ja**)ma(ˈxoʔ)	(ˈkej)ma(ˈxoʔ)
nes.ja.ma.xoʔ	(ˈnes)(ˈja.m**a**)(ˈxoʔ)	(ˈnes)(ˈjam)(ˈxoʔ)
ke.we.ja.ma.xoː.ka	(ˈke.w**e**)(ˈja.m**a**)(ˈxoː)ka	(ˈkew)(ˈjam)(ˈxoː)ka

Glosses: ‘he hits it’; ‘he paints my face’; ‘he causes him to paint my face’; ‘you paint our faces’

The vowels that undergo syncope are boldfaced in the stress step. It is easy to see that they are always in the weak position of a trochee, as expected. (Relevant additional phenomena not discussed here include apocope and immunity of root-final vowels to MCS. See Gouskova (2003) for an analysis of these phenomena that is compatible with the proposals made here.)

An interesting detail of (37) is the choice between applying syncope to the weak footed syllable [ja] or the unfooted syllable [ma] of [(ˈke.**ja**)**ma**(ˈxoʔ)]. An analogous situation occurs in Dutch. Dutch reduces the vowel /o/ more readily in a

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[11] This form has iambic lengthening as well as syncope—see Sect. 7.

[12] In (37), deletion of the first of two vowels in hiatus is assumed to occur before the stress step: /jakapa-oʔ/ → [jakapoʔ]. This is not essential to the analysis, but it simplifies the discussion.

weak footed syllable than an unfooted one (Booij 1977: 130–135; Kager 1989: 312–317): [(ˈeko)no(ˌmi)] ∼ [(ˈekə)no(ˌmi)] ∼ [(ˈekə)nə(ˌmi)], but *[(ˈeko)nə(ˌmi)] *economie* ‘economy’.[13] This observation means that weak footed syllables are poorer licensers of vowel features than unfooted syllables. It leads de Lacy (2006: 225ff) to propose that (the equivalent of) $*\text{V-PLACE}_{\text{weak}}$ has a less stringent (= more specific) counterpart $*\text{V-PLACE}_{\text{weak-in-foot}}$. The first [o] in [(ˈeko)no(ˌmi)] violates both of these constraints, but the second [o] violates only $*\text{V-PLACE}_{\text{weak}}$. Likewise, in Tonkawa [(ˈke.ja)ma(ˈxoʔ)], the first [a] violates both constraints, but the second [a] violates only $*\text{V-PLACE}_{\text{weak}}$.

Tonkawa is not the only language with left-to-right trochaic syncope. Other reported cases include Southeastern Tepehuan (Blumenfeld 2006: 196ff; Willett 1982; Willett 1991), Tundra Nenets (Staroverov 2006), Archaic Latin (Blumenfeld 2006: 188ff), Indo-European (Borgstrøm 1949; Kager 1993: 428; Lightner 1972: 378), and Old Irish (Kager 1993: 428; Lightner 1972: 378; Thurneysen 1961).

5.4 Right-to-left trochees

The final lobe of the predicted MCS typology is right-to-left trochaic syncope, which is based on right-to-left trochaic stress:

(38) Right-to-left trochaic stress schematically

Parity	Stress step
Odd	pa(ˈtaka)(ˈbada)(ˈgana)
Even	(ˈpata)(ˈkaba)(ˈdaga)

In odd-parity words, the right-to-left trochaic syncope pattern resembles the iambic pattern, since odd numbered syllables are targeted for deletion. In even-parity words, right-to-left trochees and left-to-right trochees produce the same result.

Right-to-left trochaic stress patterns are not as common as left-to-right ones (Hayes 1995: 265–266), and consequently it is a little harder to locate solid examples of right-to-left trochaic syncope. (This typological tendency makes sense because, in the HS analysis, trochaic syncope systems are just trochaic stress systems, plus syncope.) Two possible examples are Classical Mandaic (Malone 1972, 1992, 1997) and Hindi (Ohala 1977), but the clearest case is Havlík’s Law in Slavic, usually called *jer* deletion. The Common Slavic jers were short high vowels and susceptible to deletion. When a sequence of jers occurred in adjacent syllables, the odd numbered ones counting from the right were deleted and the remaining jers were lowered to mid vowels (see (39)). In other words, syncope affects the weak syllables in a right-to-left trochaic system (Bethin 1998: 105; Zec 2003). In the following examples, which come from Zec (2003: 132–133), the jers are written as I and U:

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[13] The more reduced variants are associated with less formal speech styles.

(39) Jer deletion

Input to stress step	Stress step	Syncope and lowering steps	
sUnU	(ˈsUn**U**)	son	‘dream (nom.)’
sUnInU	s**U**(ˈnIn**U**)	snen	‘of sleep (adj. nom. sg. m.)’
pIpIrIcI	(ˈpIp**I**)(ˈrIc**I**)	peprec	‘pepper (nom. sg.)’

Observe that syncope affects unfooted syllables as well as weak footed ones. This shows that *V-PLACE$_{\text{weak}}$ dominates MAX in this language.

5.5 Other patterns

The previous sections have dealt with the three main patterns of stress and their MCS counterparts. There are some scarcer variations on the three basic stress types, and there is suggestive evidence of MCS patterns that match these variations.

Assigning right-to-left trochees with final-syllable extrametricality yields antepenultimate stress: [(ˈpata)ka]. If *V-PLACE$_{\text{weak-in-foot}}$ dominates MAX, then syncope will affect the penult in such a language. This occurs in the Old Assyrian dialect of Akkadian (Greenstein 1984: 35) (see (40)). Interestingly, the Old Babylonian dialect follows the left-to-right trochaic pattern:

(40) Syncope in Akkadian

Underlying	Old Assyrian	Old Babylonian	
ʔatalakam	ʔatalkam	ʔatlakam	‘come!’
litabuʃum	litabʃum	litbuʃum	‘clothing oneself (nom.)’
duru χumid	duruχmid	durχumid	place name

Unfortunately, underlying forms with longer sequences of light syllables do not occur.

In the initial dactyl effect (Hayes 1995: 96–98), the basic stress pattern is right-to-left trochaic, but odd-parity words have an initial trochee: [(ˈpata)ka(ˈmasa)(ˈbada)]. A possible example of MCS with this type of footing is Afar (Bliese 1981). It assigns main stress at the right but has peninitial syncope.[14]

5.6 Summary

Typology is the acid test of any analysis in OT. I have argued that the HS analysis of MCS fares rather well by this standard. It predicts the existence of certain MCS patterns, all of which appear to be attested. The same cannot be said about other approaches to MCS, as I will now argue.

6 Comparison with other approaches

The goal of this section is to illuminate the properties of the HS analysis of MCS by comparison with other analyses. I will first look at extant classic OT analyses (6.1).

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[14] I am grateful to Maria Gouskova for directing my attention to this example.

Since HS has some superficial resemblances with constraint-and-repair theories, I undertake that comparison in 6.2. Finally, in 6.3 I discuss MCS in rule-based phonology and in theories with rule-like constraints.

6.1 Classic OT analyses

Classic OT analyses of MCS have to deal with simultaneous rather than serial optimization of stress and syncope. This proves to be problematic. As Kager (1997) was the first to realize, and Blumenfeld (2006) has argued at length, classic OT cannot express the generalization that apparently underlies MCS: vowels are deleted only in those positions where they would be unstressed if they were not deleted. As we have seen, this generalization follows straightforwardly from the HS analysis. The reasons why it is inexpressible in classic OT will emerge when we examine the various attempts that have been made to grapple with MCS: the monopod analysis, the polypod analysis, and the pseudo-syncope analysis.

6.1.1 Monopod analysis

Kager (1997) proposes a monopod analysis of Southeastern Tepehuan, and I will try to adapt it to Aguaruna. It is a monopod analysis because the grammar limits words to exactly one left-aligned foot. This is accomplished by ranking Align-Left(foot, word) over Exhaustivity(word):

(41) Monopod footing

/iʧinakaŋuminakɨ/	Align-L(ft, wd)	Exh(word)
a. → |(ˈiʧin)kaŋminak|		3
b. |(ˈiʧi)(ˈnaka)(ˈŋumi)(ˈnakɨ)|	12 **W**	**L**

In the monopod analysis, it does not matter whether the foot is iambic or trochaic—just that it is there—so I have simply assumed that it is trochaic.

Because only one foot is allowed, and it is maximally disyllabic, syncope is the only way of reducing the number of Exhaustivity(word) violations in the rest of the word. This requires that Exhaustivity(word) dominate Max:

(42) Monopod analysis of MCS

/iʧinakaŋuminakɨ/	Align-L(ft, wd)	Exh(word)	Max
a. → |(ˈiʧin)kaŋminak|		3	3
b. |(ˈiʧi)nakaŋuminakɨ|		6 **W**	**L**

Elimination of *all* unfooted syllables is impossible for phonotactic reasons; for example, *[(iʧinkŋmnk)] incurs multiple violations of undominated *Complex-Coda.

The monopod analysis has a problem: with only one foot per word, it cannot easily distinguish among candidates that differ in the choice of which vowels to delete. The following tableau illustrates:

(43) Monopod analysis of even-parity input

/iʧinakaŋuminakɨ/	ALIGN-L(ft, wd)	EXH(word)	MAX
a. → |(ˈiʧin)kaŋminak|		3	3
b. |(ˈiʧi)nakŋumnak|		3	3
c. |(ˈiʧin)kaŋumnak|		3	3
d. |(ˈiʧnak)ŋumnak|		2	3

Candidates (43b)–(43d) perform as well as, or better than, the intended winner (43a) on this constraint hierarchy, but they exhibit different patterns of syncope. Some other constraint or constraints are necessary to rule them out.

Candidate (43d) is the easiest to deal with. The proponent of the monopod analysis could just assume that CVC syllables are heavy in this language and that feet are iambic. In that case, (43d) contains a (HˈH) foot. Feet of this type are disfavored by the Iambic/Trochaic Law (47). Ranked above EXHAUSTIVITY(word), the Iambic/Trochaic Law will correctly favor the winner over (43d).

Candidates (43b) and (43c) present a bigger challenge to the monopod analysis. ALIGN-RIGHT(foot, word) is no help, since all three candidates have three syllables to the right of the foot.

It seems clear that metrical constraints are of no help in choosing among (43a)–(43c). What about other constraints? Faithfulness constraints will not decide, since all three candidates are equally unfaithful. Syllabic constraints like NO-CODA are also useless, since these candidates contain exactly the same numbers of CV and CVC syllables.

What about a constraint that, say, disfavors [ŋ] in onset position? It would correctly rule out (43b) and (43c). Or perhaps (43a) is preferred to (43c) because (43a) preserves the final vowel in the root /iʧinaka/. These suggestions miss the point. They rely on details of the segmental or morphological composition of this particular example. The goal is to analyze a general pattern of vowel loss that is pervasive in the language. Any analysis that relies on details of the morphological or segmental composition of particular words is doomed to failure, since it cannot account for this general pattern.

The basic problem with the monopod analysis is now clear. Observationally, MCS follows alternating patterns that are similar to stress patterns. In the HS analysis, the reason for this is that MCS affects a representation in which alternating stress has already been assigned. By its nature, the monopod analysis cannot use alternating stress to determine where syncope occurs. Instead, it globally optimizes the count of unfooted syllables. This optimization can look a bit like an alternating pattern, because phonotactic requirements usually block syncope in adjacent syllables, but it has problems in deciding which vowels to delete. In contemporary phonological theory, iterative footing offers the only mechanism for controlling alternating patterns, and the monopod analysis eponymously excludes that possibility.

This failure of the monopod analysis of Aguaruna reveals a broader typological problem: the monopod analysis predicts unattested syncope phenomena. The discussion of tableau (43) showed that the monopod analysis has no way of using metrical structure to find the right winner with an even-parity input. The typological prediction of the monopod analysis is that MCS with even-parity inputs show the effect of tie-breaking non-metrical constraints that are unable to produce a consistent directional syncope pattern across diverse inputs. Contrary to this prediction, it is not the case that MCS works this way in *every* language; in fact, MCS apparently works this way in *no* language.

This problem with the monopod analysis reveals an important point about analyses of MCS generally, including the HS analysis. Suppose that the rankings are arranged so that the stress step assigns only a single foot and quits. Then the syncope step will face the same ambiguity seen in (43)—an unwelcome result. The obvious solution is to deny that the monopod is a possible stress pattern, so that the stress step cannot terminate when there are more syllables to parse. The evidence for the existence of the monopod stress pattern is purely negative—occasionally, grammars do not mention secondary stress or at best report the analyst's inability to detect it. This *argumentum ex silentio* is not very compelling. Furthermore, "only one foot per word" is not a legitimate inference from "no secondary stresses". Since the realization of prominence varies from language to language, it is entirely possible for feet to be present in surface structure but not interpreted phonetically (Hayes 1995: 119; McCarthy 2003a: 112). In sum, the case for monopod languages is very weak indeed. And if such languages are impossible, then so is the monopod analysis of MCS.

It is a harder problem to eliminate monopod languages from the predicted typology by changing the constraint set, though the discussion in Kager (2001) and McCarthy (2003a) indicates some initial progress in this direction. As yet, I do not have a full account of how monopod languages are to be eliminated from the typology, but this is a first step.

6.1.2 Polypod analysis

The first and best exemplar of the polypod analysis is Gouskova's (2003) account of syncope in Tonkawa. Words are parsed into multiple feet, and syncope is a means of optimizing that parse.

In a polypod analysis of Aguaruna, the proximate cause of syncope can be the same as it is in the HS analysis, *V-Place$_{\text{weak}}$. The polypod analysis also resembles the HS analysis in another respect: both use metrical structure to determine which vowels delete and which remain. The difference is that the polypod analysis is assigning metrical structure and doing syncope simultaneously, whereas the HS analysis intrinsically orders metrical structure assignment before syncope. This turns out to be rather a big difference indeed.

The problem with doing stress and syncope simultaneously is that it is possible to end up with essentially identical metrical structures despite different choices of which vowels to delete. Tableau (44) presents a case from Aguaruna where the optimal candidate and a candidate with a different deletion pattern tie on all of the constraints under discussion:

(44) Tie for optimality in polypod analysis

	/itʃinakaŋumina/	Align-L (ft, wd)	Align-R (ft, wd)	*V-Pl$_{\text{weak}}$	Max	Ft-Bin	Exh(wd)
a. →	|(ˈitʃin)(ˈkaŋmin)|	2	2	2	3		
b.	|(ˈitʃnak)(ˈŋumin)|	2	2	2	3		

As in the previous section, I have assumed that feet are trochaic, but the problem would be the same if they were iambic.[15]

This example illustrates a general problem with the polypod analysis of Aguaruna: it cannot account for the observation that the second syllable does not undergo syncope. In the HS analysis, this observation follows almost trivially: the second syllable never undergoes syncope because it has already been stressed. This explanation is not available in a classic OT analysis. The candidates in (44) differ in whether or not the second syllable has been deleted, but they are equally harmonic according to all of the constraints. Capturing the generalization that the second syllable never deletes requires that iambic stress precede syncope, but that serial statement is obviously outside the capacity of classic OT, which has to optimize the consequences of syncope and stress assignment in parallel.

The existence of ties like (44) leads to the same typological problem that we saw with the monopod analysis. When the constraints that should be deciding the pattern of syncope fail to make a choice, any other constraint, even a normally inactive one, can emerge to be decisive. This predicts that there will be languages with MCS where the choice between (44a) and (44b) depends on specific details of the segmental or morphological composition of each input, because low-ranking constraints that refer to segmental structure or the morphology emerge to settle the tie. Then MCS would not produce a consistent directional syncope pattern across inputs that vary in their segmental or morphological composition.

It is important to realize that the HS analysis would have the same problem with (44) as the classic OT polypod analysis does, *if not for the intrinsic ordering results of* Sect. 3.2. Here is why. Suppose, contrary to the argument in 3.2, there were a constraint *V-Place$_{\text{unstressed}}$ that could compel syncope prior to metrical structure assignment. Because of this constraint, [itʃinkaŋmin] and [itʃnakŋumin] are contenders for local optimality at the syncope step. They equally violate *V-Place$_{\text{unstressed}}$ and Max, so the choice between them may fall to some lower-ranking constraint that relies on specific details of their segmental or morphological composition. The result is a non-existent system of MCS where the choice of which vowels to delete is not determined by metrical constraints and there is no directionally iterative pattern.

In the real HS analysis of Aguaruna, the pattern of syncope in [(itʃnak)(ŋumin)] (44b) is an impossibility because it involves deleting stressed vowels, and that is not harmonically improving: *<itʃinakaŋumina, (iˈtʃ**i**)(naˈk**a**)(ŋuˈmi)n**a**, itʃnakŋumin>. (Recall from 3.1 that gradualness rules out deleting a vowel and simultaneously shifting its stress.) In HS, a language can have this pattern of syncope, but only if trochaic feet are first assigned from left-to-right. The HS analysis sharply differentiates the iambic and trochaic left-to-right syncope patterns, and Aguaruna is clearly iambic. The polypod analysis has no way of getting that result. In HS, because of intrinsic ordering, MCS *deals with the results* of prior stress assignment. The polypod analysis

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[15] Tableau (44) presupposes that surface CVC syllables are light (or feet are quantity-insensitive). If CVC syllables are instead assumed to be heavy, with syncope producing (ˈCVC) feet, then the problems are even worse. From /itʃinaka/, *[|(ˈitʃ)(ˈnak)|] easily beats [|(ˈitʃi)(ˈnak)|]. Both Align-L(foot, word) and *V-Place$_{\text{weak}}$ favor *[|(ˈitʃ)(ˈnak)|]. Like the analysis in (44), this alternative version of the polypod analysis is unable to account for the immunity of peninitial syllables from deletion.

permits more complex interactions of MCS and metrical-structure assignment, to its detriment.

6.1.3 Pseudo-syncope analysis

Alderete's (2001) analysis of Aguaruna is based on the premise that vowel deletion is a kind of pseudo-syncope, with words syllabified as if the deleted vowels were still present. In traditional derivational terms, one would say that pseudo-syncope is syncope without resyllabification, so the syllables that have undergone syncope are still there even though they have lost their nuclei.

For instance, the surface form of /iʧinakana/ is quinquesyllabic [(iˈʧi)(nΔˈka)nΔ] in the pseudo-syncope analysis. Although the vowels after both [n]s have deleted, the [n]s are parsed as onsets of degenerate syllables. This move folds the stress and syncope steps into a single representation. The stress constraints evaluate [(iˈʧi)(nΔˈka)nΔ] and find that it has all of the characteristics of a good iambic parse, so it beats candidates like trochaic *[(ˈiʧΔ)(ˈnakΔ)na]. The syncope constraints evaluate [(iˈʧi)(nΔˈka)nΔ] and find that it has no non-initial unstressed vowels, so it beats candidates like more faithful *[(iˈʧi)(naˈka)na].

Unlike the other classic OT analyses discussed in this section, the pseudo-syncope analysis is just as successful as the HS analysis in determining which vowels delete and which vowels remain in Aguaruna. It correctly captures the generalization that Aguaruna deletes vowels that are unstressed in an iambic parse. But the pseudo-syncope analysis has a different problem: there is plenty of evidence from Aguaruna and other languages that syncope can result in resyllabification.

Because there is no resyllabification, the pseudo-syncope analysis parses the highlighted consonants in [iʧi**n**ka**n**] (= [(iˈʧi)(nΔˈka)nΔ]) as onsets of degenerate syllables, not as codas. This syllabification is at odds with all known reports of how this language actually syllabifies consonant clusters (Asangkay Sejekam 2006: Sect. 6; Payne 1990: 166; Pike and Larson 1964: 64). It is also contradicted by a substantial body of phonological evidence:

- We saw in (17) that high tone shifts rightward to the head of the foot when the vowel that originally bore the tone undergoes syncope. But high tone shifts to the left, into the previous foot, if rightward shift would put it onto the final syllable: <u.ŋu.ʃí.nu.mi, (uˈŋu)(ʃ**í**ˈnu)mi, (uˈŋ**ú**ʃ)(ˈnum)>, not *<u.ŋu.ʃí.nu.mi, (uˈŋu)(ʃ**í**ˈnu)mi, (uˈŋuʃ)(ˈn**ú**m)>. This generalization rests on the assumption that [num] is a single final syllable, but in the pseudo-syncope analysis [nu] is not the final syllable, so rightward shift should be possible: *[(uˈŋu)(ʃΔˈn**ú**)mΔ].
- We saw in 4.4.4 that homorganic NC clusters alternate with N when the following vowel syncopates: /taku**mp**ɨŋumɨka/ → [ta.ku**m**.ŋu.mɨk]. The phonological rationale for this process is straightforward if syncope is real deletion, but it is inexplicable under the pseudo-syncope analysis, since the consonant that deletes is an onset: *[ta.kum.**p**Δ.ŋu.mɨ.kΔ].
- Phonemic nasal vowels dissimilate to oral before tautosyllabic [ŋ]: /majãĩ-ŋu/ → [ma.jaiŋ] 'my breath'. Under the pseudo-syncope analysis, however, [ŋ] is not tautosyllabic with the preceding vowels in this word, so there should be no denasalization: *[ma.jãĩ.ŋΔ].

- In /aŋutaʃakam/ → [aŋutʧakam] 'also old', /ʃ/ becomes [ʧ] after [t]. Under a conventional view of syncope, this process is completely unremarkable. But with pseudo-syncope, it presents difficulties, since the [t] and [ʧ] are not strictly adjacent to one another: [a.ŋu.tΔ.ʧa.kam].
- [ŋ] in coda position alternates with [h̃] in onset position: [suŋ.kuŋ] ∼ [suŋ.kũ.h̃ãn] 'influenza (nom. ∼ acc.)'. Since the underlying form of this word is /suŋkuŋa/, the second [ŋ] has to be an onset under the pseudo-syncope analysis, so it should be pronounced as [h̃]: *[suŋ.kũ.h̃Δ].

As we will see in 6.3, Aguaruna is not the only language where pseudo-syncope is untenable. This is not to say that pseudo-syncope is impossible universally; Kager (1997) makes a solid case that pseudo-syncope is the right way to analyze Carib, and there is also evidence for pseudo-syncope in Bedouin Arabic (McCarthy 2003b). But pseudo-syncope is not a general solution to the problem of stress-syncope interactions.

6.2 Constraint-and-repair theory

Phonological theories that mix rules and constraints have been around since the 1970's. These theories share with OT the idea that output constraints are a major factor in triggering and/or blocking processes. Furthermore, they share with HS the assumption that output constraints can have these effects over the course of a derivation. Despite these similarities, there are also important differences. Here, I will focus on the comparison between HS and the Theory of Constraints and Repair Strategies (TCRS) (Paradis 1988a, 1988b, 1997; Paradis and El Fenne 1995). This comparison has been aided by the analysis of TCRS in Prince and Smolensky (1993/2004: 252–257).

TCRS recognizes three basic elements: constraints, which are inviolable, surface-true phonotactic requirements; repairs, which are context-free operations that insert or delete a phonological element (Paradis 1997: 532; Paradis and El Fenne 1995: 187); and rules, which express generalizations that do not have a basis in a language's phonotactics (Paradis 1988a: 83–86). Morphology and the rules have the potential to create constraint violations. These violations are eliminated by repairs. Like HS and unlike classic OT, TCRS has derivations with intermediate stages (Paradis 1997).

TCRS can be illustrated with the following example from Yowlumne (Yawelmani). This language has processes of apocope and closed-syllable shortening, illustrated in (45):

(45) Yowlumne apocope (Kisseberth 1970a; Newman 1944)

Underlying	Surface	
/taxaː-k^{ʔ}a/	[ta.xak^{ʔ}]	'bring!'
/taxaː-mi/	[ta.xam]	'having brought'

[CVːC]$_{\sigma}$ syllables are prohibited (Newman 1944: 25), so shortening can be related to an inviolable phonotactic constraint (Kisseberth 1970a). I will refer to this constraint as *[CVːC]$_{\sigma}$. In TCRS terms, shortening is the repair for violations of *[CVːC]$_{\sigma}$.

Unlike shortening, apocope has to be a rule rather than a repair in TCRS because there is no phonotactic basis for it. Yowlumne cannot have a constraint *V# because final vowels are preserved after a consonant cluster (e.g., [xat.k^{ʔ}a] 'eat!'), and constraints in TCRS are inviolable. Therefore, the derivation of /taxaː-k^{ʔ}a/ begins with a rule of apocope applying to yield [ta.xaːk^{ʔ}]. Then the violation of *[CVːC]$_{\sigma}$ in [ta.xaːk^{ʔ}] is detected. This invokes *[CVːC]$_{\sigma}$'s repair, shortening, to give the surface form [ta.xak^{ʔ}]. In summary, repairs are constraint- and language-specific responses to violations of inviolable output constraints; rules are operations that cannot be attributed to inviolable constraints.

If TCRS is applied to MCS, we get something like the following. Stress assignment has to be a rule rather than a repair for two reasons. First, there is no phonotactic constraint to trigger the repair. EXHAUSTIVITY(word) is the obvious candidate for such a constraint, but Aguaruna and most other languages leave syllables unfooted in some circumstances. In OT, these circumstances are defined by higher-ranking constraints, but TCRS lacks that option—its constraints are inviolable. Second, repairs are limited to simple context-free operations, and stress assignment is much too complex and context-dependent to qualify as a repair in this respect.

Strictly speaking, syncope cannot be a repair either, at least in Aguaruna. The problem is that *V-PLACE$_{\text{weak}}$ is violated, since some weak syllables survive in two contexts, initially and finally (see 4.4.1). In OT, *V-PLACE$_{\text{weak}}$ is active but violated when crucially dominated. Since constraints in TCRS are inviolable output conditions, syncope in Aguaruna has to be a rule as well. In that case, the constraints and repairs of TCRS are contributing nothing to the analysis of MCS in Aguaruna. This looks like a dead end.

There is an ad hoc way of getting around this obstacle. The move is to replace *V-PLACE$_{\text{weak}}$ with a more specific constraint that is surface-true. Since Aguaruna categorically prohibits weak syllables word-medially, something like *V-PLACE$_{\text{weak}}$/VC$_0$__C$_0$V will be necessary. Most instances of syncope can then be treated as a repair for violations of *V-PLACE$_{\text{weak}}$/VC$_0$__C$_0$V, and TCRS can analyze this language in a way that is abstractly similar to Yowlumne: the rule of stress assignment creates violations of *V-PLACE$_{\text{weak}}$/VC$_0$__C$_0$V, and those violations are repaired by deleting the weak vowel.

Like HS, this analysis establishes an intrinsic ordering relationship between stress assignment and syncope: syncope repairs violations that stress assignment creates, so syncope is inapplicable until stress has been assigned. The resemblance ends there, however. Because HS incorporates the main elements of classic OT, it differs from TCRS in nearly all of the ways that classic OT differs from TCRS. Here, I will mention two differences that bear particularly on MCS (see Prince and Smolensky 1993/2004: 238ff, for more complete discussion of such differences).

In TCRS, constraints must state phonotactic truths, but in OT and HS, they need not, and typically do not. This assumption leads to various problems for TCRS. It is largely responsible for the otherwise unmotivated distinction between rules and repairs. Yowlumne apocope has to be a rule because *V# cannot be a constraint, since it is not surface-true. Apocope could be treated as a repair if the language had the more complicated constraint *VCV#, but this constraint stipulates something that should be explained: apocope is blocked in [xat.k^{ʔ}a] for phonotactic reasons. Likewise, Aguaruna stress assignment has to be a rule rather than a repair because EXHAUSTIVITY(word) is not a phonotactic truth of this language. In an OT analysis, violations of EXHAUSTIVITY(word) are explained by higher-ranking constraints, but this mode of analysis is not available in TCRS.

In TCRS, constraints have no way of influencing rules—they are limited to triggering repairs of the violations that rules create, after the fact. This presents problems for the larger theory of *V-PLACE$_{\text{weak}}$ and similar constraints (see 3.2). In HS and OT generally, *V-PLACE$_{\text{weak}}$ has diverse effects: not only is it a trigger for syncope, but it also affects stress assignment. De Lacy (2002: 113ff) describes various languages whose stress patterns are influenced by constraints that, like *V-PLACE$_{\text{weak}}$, ban high-sonority vowels from metrically weak positions. In other words, the same markedness constraint may have different effects in different languages—a very familiar consequence of OT. TCRS has no way of recognizing this unity.

In summary, TCRS would be more successful in analyzing MCS if it eliminated the distinction between rules and repairs and if it had ranked, surface-violable constraints. It would also be a very different theory—unrecognizable as TCRS, and needing only the addition of faithfulness constraints to be very close to if not indistinguishable from HS.

6.3 Rules and rule-like constraints

In rule-based phonology within the *SPE* tradition (Chomsky and Halle 1968), MCS occurs whenever a syncope rule that targets unstressed vowels is extrinsically ordered after a stress assignment rule. The ordering is extrinsic because the standard theory does not provide for intrinsic or predictable ordering except in very limited circumstances—e.g., the parenthesis notation or its successor, the Elsewhere Condition, neither of which is applicable here.

An anonymous reviewer asks what it would take to get intrinsic ordering of stress before syncope in rule-based phonology. It can be done, if two rather dubious assumptions are made. First, *all* vowels must be stressed in underlying representation. Second, assigning stress to some vowel(s) causes destressing of all other vowels. (This is approximately the Stress Reduction Convention of Chomsky and Halle 1968: 17 et passim.) Then there will be no unstressed vowels until after stress has been assigned by rule. Clearly, both assumptions are being made only to get intrinsic ordering; they are not basic to the architecture of rule-based phonology nor are they independently motivated. In both respects, they differ from the intrinsic ordering results in HS.

Beyond this, we cannot say much about MCS in rule-based phonology without considering the diverse ways in which analysts have sought to put a check on that theory's excessive power. This would be a very long and distracting enterprise, particularly since, to my knowledge, the typological properties of MCS have never been explicitly addressed in any rule-based theory of phonology.

Typology is the primary motivation for two theories of rule-like constraints, targeted constraints (Wilson 2000, 2001) and procedural constraints (Blumenfeld 2006). These approaches are somewhat similar to each other, and they share a similar liability: they will only work if MCS is always analyzed as pseudo-syncope.

A targeted constraint makes an explicit comparison between two forms that differ in exactly one way. For instance, targeted NO-CODA says something like "*Cand1* is more harmonic than *Cand2* if *Cand1* and *Cand2* are identical except that *Cand1* lacks a coda consonant that is present in *Cand2*”. Thus, targeted NO-CODA says that [pa] is more harmonic than [pat], but unlike the standard NO-CODA constraint it says nothing about the relative harmony of [pa] and [pa.tə], which do not differ in the prescribed way.

Applying this idea to MCS gives us a constraint like the following:

(46) Targeted constraint for MCS
Cand1 is more harmonic than *Cand2* if *Cand1* is identical to *Cand2* except that an unstressed vowel in *Cand2* is absent from *Cand1*.

This constraint says that [(ˈpa.tΔ)ka] is more harmonic than [(ˈpa.ta)ka], since they differ in exactly the way prescribed in the definition. Thus, it could be useful in analyzing MCS in a language like Carib that has pseudo-syncope. But it says nothing about the relative harmony of [(ˈpa.ta)ka] and [(ˈpat)ka], where resyllabification of [t] means that the “identical except that” clause is not fulfilled. For this reason, it is not helpful in analyzing languages with true syncope, such as Aguaruna.

The procedural constraint responsible for MCS is defined as “If a nucleus is in a weak branch of a foot, it is empty” (Blumenfeld 2006: 173). Obviously, given this definition, procedural constraint theory requires all cases of MCS to be analyzed as pseudo-syncope (Blumenfeld 2006: 172). Again, Aguaruna is problematic.

Since these two theories with rule-like constraints require all cases of MCS to be analyzed as pseudo-syncope, it is worth emphasizing that this cannot be correct as a general fact about language. Besides the evidence from Aguaruna, there is much evidence from other languages against pseudo-syncope:

- Many languages limit syncope to a VC___CV context, the “two-sided open syllable” of Kuroda (1967). The standard explanation for this context is that syncope is blocked in other contexts by constraints on syllable structure. For instance, Cairene Arabic deletes unstressed vowels in this context, but not otherwise: /fihim-u/ → [ˈfih.mu] ‘they understood’ versus /fihim-na/ → [f**i**ˈhim.na], *[ˈfhimna] ‘we understood’. The usual story is that syncope is blocked in *[ˈfhim.na] because of the *COMPLEX-ONSET violation. But if syncope always leaves an empty nucleus, then this explanation is unavailable, since *[fΔ.him.na] does not have a complex onset.
- Coda conditions can also block syncope. In Tonkawa (5.3), syncope is blocked by an undominated constraint against glottalized codas (Kisseberth 1970b: 124–125): /we-s^{ʔ}ako-oʔ/ → [(ˈwe.s^{ʔ}a)(ˈkoʔ)], *[(ˈwe**s**^{ʔ})(ˈkoʔ)] ‘he scrapes them’. The independently motivated constraint against glottalized codas cannot block syncope under the pseudo-syncope analysis, however, since the glottalized consonant is not a coda: *[(ˈwe.s^{ʔ}Δ)(ˈkoʔ)].[16]

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[16] An anonymous reviewer suggests that pseudo-syncope could be an intermediate step in an HS derivation of true syncope—e.g., <…, ja.ka.poʔ, (ˈja.ka)(ˈpoʔ), (ˈja.**k**Δ)(ˈpoʔ), (ˈjak)(ˈpoʔ)> in Tonkawa. This analysis will not work. The problem is that the constraint against glottalized codas cannot block the syncope step in *<…, we.s^{ʔ}a.koʔ, (ˈwe.s^{ʔ}a)(ˈkoʔ), (ˈwe.**s**^{ʔ}Δ)(ˈkoʔ)>, though it will block any later attempts at resyllabifying the [s^{ʔ}] into coda position. The predicted result is therefore *[we.**s**^{ʔ}.koʔ] rather than [we.**s**^{ʔ}**a**.koʔ].

- Processes that affect codas will also affect consonants that are in coda position by virtue of syncope. An example is coda debuccalization in Panare (Gouskova 2002; Payne and Payne 2001): /n-utu-ʧah/ → [ˌnu**h**ˈʧah] 'he gave it (immediate past)'; /j-utu-ñe/ → [ˌju**ʔ**ˈñe] 'he is going to give it'. But if these consonants are onsets of degenerate syllables, it makes no sense for them to debuccalize.

To reiterate a point made earlier, pseudo-syncope may be right for some languages, but it is surely wrong as a claim about all languages.

7 Metrically-conditioned shortening and lengthening

Like MCS, metrically-conditioned shortening and lengthening processes improve harmonically on the results of prior stress assignment. They do this by bringing disyllabic feet into better conformity with their quantitative ideals, which appear in (47) (Hayes 1987, 1995; Kager 1993; McCarthy and Prince 1986/1996; Mester 1994; Prince 1990 and others).

(47) Quantity in disyllabic feet
a. Trochees should have equal quantity—(ˈpata), not (ˈpaːta) or (ˈpataː).
b. Iambs should be light-heavy—(paˈtaː), not (paˈta) or (paːˈta).

In the cited works and elsewhere, there are various proposals about how to express these requirements as formal constraints. For present purposes, it is harmless to lump them together as the constraint I/TL, which abbreviates the Iambic/Trochaic Law of Hayes (1995).

A process that enforces requirement (47a) is trochaic shortening. The columns in (48)–(50) labeled "Stress step" and "Shortening step" anticipate the HS analysis, which will be discussed after the examples.

(48) Trochaic shortening in Tonkawa (Gouskova 2003; Hoijer 1933, 1946)

Input to stress step[17]	Stress step	Shortening step	
xa.kaː.noʔ	(ˈxa.kaː)(ˈnoʔ)	(ˈxa.k**a**)(ˈnoʔ)	'he throws it far away'
ke.jaː.loː.noʔ	(ˈke.jaː)(ˈloː)(ˈnoʔ)	(ˈke.j**a**)(ˈloː)(ˈnoʔ)	'he kills me'

(49) Trochaic shortening in Latin (Allen 1973; Mester 1994)

Underlying	Stress step	Shortening step	
/putaː/	(ˈpu.taː)	(ˈpu.t**a**)	'think! (sg.)'
/woloː/	(ˈwo.loː)	(ˈwo.l**o**)	'I want'
/diːkitoː/	(ˈdiː)(ˌki.toː)	(ˈdiː)(ˌki.t**o**)	'say! (fut. sg.)'
/dikseroː/	(ˈdik)(ˌse.roː)	(ˈdik)(ˌse.r**o**)	'I said'

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[17] For simplicity, I have suppressed the derivational step where V-V hiatus is resolved by deletion.

(50) Trochaic shortening in Fijian (Dixon 1988; Hayes 1995)

Underlying	Stress step	Shortening step	
/m͡buː.ŋ͡gu/	(ˈm͡buː.ŋ͡gu)	(ˈm͡b**u.**ŋ͡gu)	‘my grandmother’
/siː.βi/	(ˈsiː.βi)	(ˈs**i.**βi)	‘exceed’

A process that enforces requirement (47b) is iambic lengthening:

(51) Iambic lengthening in Hixkaryana (Derbyshire 1985; Hayes 1995)

Underlying	Stress step	Lengthening step
/mɨhananɨhno/	(mɨˈha)(naˈnɨh)no	(mɨˈh**aː**)(naˈnɨh)no
/tohkurʲehonahaʃaka/	(ˈtoh)(kuˈrʲe) (hoˈna)(haˈʃa)ka	(ˈtoh)(kuˈrʲ**eː**)(hoˈn**aː**)(haˈʃ**aː**)ka

Glosses: ‘you taught him’; ‘finally to Tohkurye’

In HS, trochaic shortening and iambic lengthening are, like MCS, intrinsically ordered after assignment of metrical structure. To show this, I will work through one of the examples of trochaic shortening, Tonkawa. Recall from Sect. 5 (and ultimately from Gouskova 2003, 2007) that Tonkawa has a left-to-right trochaic stress system. Shortening affects the second syllable of the word when the first is light: /CVCVː.../ → [CVCV...]. Shortening therefore ensures that the first two syllables form a trochaic foot that conforms with clause (47a) of I/TL.

In HS, analyzing this pattern requires first building a (ˈCVCVː) trochee, in spite of I/TL, and then bringing it into conformity with I/TL by shortening: <..., xa.kaː.noʔ, (ˈxa.kaː)(ˈnoʔ), (ˈxa.ka)(ˈnoʔ)>. At the stress step, the competitors for local optimality include the three parses in (52a)–(52c). Since (52a) reflects the presumed surface stress pattern, it must be the most harmonic of these alternatives. The choice of (52a) requires the rankings supported by this tableau: ALIGN-LEFT(word, foot) and FOOT = TROCHEE dominate I/TL and FOOT = IAMB.

(52) Rankings needed for Tonkawa stress step
Input: [xa.kaː.noʔ]

	Candidates for stress step	ALIGN-L(wd, ft)	FT = T	I/TL	FT = I
a. →	(ˈxa.kaː)(ˈnoʔ)			1	1
b.	xa(ˈkaː)(ˈnoʔ)	1 **W**		**L**	**L**
c.	(xaˈkaː)(ˈnoʔ)		1 **W**	**L**	**L**

At the next step in the derivation, the choice is between staying the same, as in [|(ˈxa.kaː)(ˈnoʔ)|] (53b), or shortening the long vowel in the trochee’s weak syllable, as in [|(ˈxa.ka)(ˈnoʔ)|] (53a). Since shortening wins, I/TL must dominate the constraint against vowel shortening, MAX(μ):

(53) Additional ranking needed for Tonkawa shortening step
Result of stress step: [(ˈxa.kaː)(ˈnoʔ)]

	Candidates for shortening step	ALIGN-L(wd, ft)	FT = T	I/TL	FT = I	MAX(μ)
a. →	(ˈxa.ka)(ˈnoʔ)				1	1
b.	(ˈxa.kaː)(ˈnoʔ)			1 **W**	1	**L**

Tableau (53) shows that metrically conditioned shortening improves harmony if it occurs after stress assignment. On the other hand, metrically-conditioned shortening does not improve harmony if it occurs *before* stress assignment. The reason is obvious: I/TL is a constraint on feet, and so it is vacuously satisfied by footless representations. Hence, metrically-conditioned shortening, like MCS, is intrinsically ordered after stress assignment.

This analysis of Tonkawa illustrates a general strategy for analyzing metrically conditioned shortening and lengthening processes in HS. Constraints on foot parsing dominate I/TL, allowing the creation of feet that depart from the norms of quantity. But I/TL dominates faithfulness to quantity, so adjustments are made in the next step of the derivation. Similar techniques can be used for cases where subminimal feet are augmented, such as Lardil /jak/ → [ja.ka] 'fish' (Hale 1973). In this case, foot parsing takes precedence over FOOT-BINARITY, but FOOT-BINARITY dominates DEP, so there is epenthesis on the next pass through GEN and EVAL: <jak, (ˈjak), (ˈja.ka)>.

Mester (1994) criticizes a similar analysis of Latin trochaic shortening on the grounds that it requires an intermediate derivational step with an ill-formed foot: [(ˈpu.taː)]. Mester's criticism and his alternative analysis are couched in terms of a theory where well-formedness constraints are inviolable. In other words, if I/TL is truly a linguistic law that is consistently obeyed in surface structure, why is it temporarily violable at earlier stages of the derivation?

This criticism does not carry over to OT, however, since markedness constraints are violable.[18] In classic OT, a universal markedness constraint can be present in the grammar yet still be violated in surface forms. HS allows for the further possibility that a markedness constraint may be violated only at intermediate stages and obeyed in surface forms. Whether or not this happens depends on the ranking.

(The remainder of this section is the result of collaborative work with Joe Pater.)

Some of the original arguments for parallelism in OT are similarly vulnerable. This includes Prince and Smolensky's (1993/2004: 33–38) Tongan argument, as well as the English function word argument in McCarthy (2002: 146–149). Here, we will look at the Tongan argument, since it is more relevant to the topic of this article.

The salient facts are these (Churchward 1953; Feldman 1978). The foot is a bimoraic trochee aligned at the right edge of the word: [ku(ˈmaː)] 'rat', [fa(ˈle.ni)] 'this house'. When a word ends in . . . CVːCV, the long vowel is split across two syllables, the second of them onsetless, in order to make a bimoraic trochee that is aligned at the right: [po(ˈoni)] 'this night' (cf. [(ˈpoː)] 'night'); [ma(ˈama)] 'world' (cf. [maː(ˈmani)] 'this world').

In a parallel OT analysis, ONSET is crucially dominated by I/TL, ALIGN-RIGHT(word, foot), and MAX(μ):

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[18] There can be little doubt that I/TL is a violable constraint rather than a property of GEN. For instance, many languages, including Axininca Campa (15), have iambic feet without iambic lengthening.

(54) Tongan in parallel OT

	I/TL	Align-R(wd, ft)	Max(μ)	Onset
a. → po(ˈo.ni)				1
b. (ˈpoː.ni)	1 **W**			**L**
c. (ˈpoː)ni		1 **W**		**L**
d. (ˈpo.ni)			1 **W**	**L**

Long vowels that are not in the penult, such as [(ˈpoː)] and [maː(ˈmani)], satisfy the top-ranked constraints without further ado, so Onset decides, ruling out the gratuitous onsetless syllables of *[(ˈpo.o)] and *[ma.a(ˈmani)].

Prince and Smolensky criticize a rule-based derivational analysis developed by Poser (1985). In Poser's analysis, all words go through an intermediate derivational stage with one vowel mora per syllable. Stress is assigned, and then adjacent vowel moras are fused into a single long vowel unless the second of them is stressed:

(55) Tongan according to Poser (1985)

Initial syllabification	po.o.ni	po.o	ma.a.ma	ma.a.ma.ni
Stress	po(ˈo.ni)	(ˈpo.o)	ma(ˈa.ma)	ma.a(ˈma.ni)
Adjacent vowel fusion	*no change*	(ˈpoː)	*no change*	maː(ma.ni)

Their criticism of this analysis is that "the V.V syllabification must be portrayed as general in Tongan, and UG must be accordingly distorted to allow it as a real option that is independent of coalescence—an intolerable conclusion" (Prince and Smolensky 1993/2004: 36). In other words, Poser's hypothesized initial syllabification is not a possible surface syllabification in any language, and so Universal Grammar should not allow it. On this view, the posited initial syllabification stage in Tongan is inconsistent with UG principles, so the whole analysis is untenable.

This argument hinges on an empirical claim—that no language allows V.V syllabification—and a related point of theory—that no ranking of Con will produce V.V syllabification. Both are problematic. For example, heterosyllabic sequences of identical vowels are found in Modern Hebrew: [ʃa.ˈal] 'he asked', [pa.a.ˈmon] 'bell', [ta.a.ru.ˈxa] 'exhibition', [ne.e.ˈlam] 'a variable'. Among the rankings of Con that can yield V.V syllabification is one where No-Long-Vowel (abbreviated No-Long-V) and Max dominate Onset.

To conclude, I will quickly sketch an HS analysis of Tongan. At the first step, V.V syllabification prevails because of the ranking just given: No-Long-Vowel, Max ≫ Onset. See (56) and (57). (To ensure that the analysis is internally consistent, all of the tableaux include all of the relevant constraints in their correct ranking.)

(56) Tongan syllabification step: /poo/ → [po.o]

/poo/	Align-R (wd, ft)	Max	I/TL	*V-Pl$_{\text{weak}}$	No-Long-V	Onset
a. → po.o						1
b. poː					1 **W**	**L**
c. po		1 **W**				**L**

(57) Tongan syllabification step: /poo-ni/ → [po.o.ni]

/poo-ni/	Align-R (wd, ft)	Max	I/TL	*V-PL$_{\text{weak}}$	No-Long-V	Onset
a. → po.o.ni						1
b. poː.ni					1 **W**	**L**
c. po.ni		1 **W**				**L**

Then, at the stress step, right-aligned trochaic feet are assigned: [|(ˈpo.o)|], [|po(ˈo.ni)|]. Because *V-Place$_{\text{weak}}$ was vacuously satisfied before the stress step, assigning stress creates violations of it, so *V-Place$_{\text{weak}}$ must be dominated by the stress-parsing constraint Align-Right(word, foot). (The tableaux omit WdCon, since its role in stress assignment cross-linguistically has already been discussed.)

(58) Tongan stress step: [po.o] → [|(ˈpo.o)|]

po.o	Align-R (wd, ft)	Max	I/TL	*V-PL$_{\text{weak}}$	No-Long-V	Onset
a. → |(ˈpo.o)|				1		1
b. |po.o|	1 **W**			2 **W**		1

(59) Tongan stress step: [po.o.ni] → [|po(ˈo.ni)|]

po.o.ni	Align-R (wd, ft)	Max	I/TL	*V-PL$_{\text{weak}}$	No-Long-V	Onset
a. → | po(ˈo.ni)|				2		1
b. |po.o.ni|	1 **W**			3 **W**		1
c. |(ˈpo.o)ni|	1 **W**			2		1

Because representations that lack metrical structure vacuously satisfy *V-Place$_{\text{weak}}$, this constraint could have no effect on the syllabification step in (56) and (57). But now that stress has been assigned, it is relevant, disfavoring all remaining unstressed syllables. Fusion of heterosyllabic sequences of identical vowels offers an opportunity to eliminate some unstressed syllables. Any enthusiasm for syllable fusion is tempered, however, by I/TL, which dominates *V-Place$_{\text{weak}}$ and therefore prevents the creation of (ˈCVː.CV) trochees. The following tableaux complete the picture:

(60) Tongan fusion step: [|(ˈpo.o)|] → [|(ˈpoː)|]

|(ˈpo.o)|	Align-R (wd, ft)	Max	I/TL	*V-PL$_{\text{weak}}$	No-Long-V	Onset
a. → |(ˈpoː)|					1	
b. |(ˈpo.o)|				1 **W**	**L**	1 **W**
c. |(ˈpo)|		1 **W**			**L**	

(61) Tongan fusion step: [|po(ˈo.ni)|] does not change

<table>
<tr><th></th><th>|po(ˈo.ni)|</th><th>Align-R (wd, ft)</th><th>Max</th><th>I/TL</th><th>*V-PL$_{weak}$</th><th>No-Long-V</th><th>Onset</th></tr>
<tr><td>a. →</td><td>| po(ˈo.ni)|</td><td></td><td></td><td></td><td>2</td><td></td><td>1</td></tr>
<tr><td>b.</td><td>|(ˈpoː.ni)|</td><td></td><td></td><td>1 W</td><td>1 L</td><td>1 W</td><td>L</td></tr>
<tr><td>c.</td><td>|(ˈpoː)ni|</td><td>1 W</td><td></td><td></td><td>1 L</td><td>1 W</td><td>L</td></tr>
<tr><td>d.</td><td>|(ˈponi)|</td><td></td><td>1 W</td><td></td><td>1 L</td><td></td><td>L</td></tr>
</table>

This section has shown how metrically conditioned shortening, lengthening, and syllable fusion are accommodated in HS. The intrinsic ordering results of 3.2 had a central explanatory role here, just as they did in the analysis of MCS. Along the way, we have seen how one of the principal arguments in support of parallel OT, Tongan, can be turned into an HS analysis.

8 Conclusion

Syncope processes often have the effect of eliminating unstressed syllables. In such cases, how do stress and syncope interact? In rule-based phonology, the rules that assign metrical structure are extrinsically ordered before the syncope rule, which targets unstressed syllables. In classic OT works by Kager (1997) and Gouskova (2003), syncope and metrical-structure assignment occur in parallel, and syncope is one of the factors that determine how metrical structure is optimized.

The proposal developed here is a blending of these two approaches. From rule-based phonology comes the idea that the interaction between metrical-structure assignment and syncope is best modeled by a serial derivation. From classic OT comes the idea that syncope improves the harmony of metrical structure. The effects of metrical-structure assignment and syncope are optimized serially rather than in parallel. A key element of the proposal is the demonstration that metrical-structure assignment and metrically-conditioned syncope are intrinsically ordered.

The argument for this blended approach comes principally from language typology. Classic OT analyses of metrically-conditioned syncope predict unattested systems and are unable to accommodate all attested systems. In contrast, the proposal here has a good fit between prediction and observation. It predicts that every common stress pattern should have a *Doppelgänger* with deletion of unstressed vowels, and that seems to happen.

I have also extended these results to three other metrically conditioned processes, trochaic shortening, iambic lengthening, and syllable fusion. These phenomena illustrate some of the broader entailments of the proposal: when metrical structure conditions segmental alternations, the segmental alternations are affected by, but cannot affect, the metrical structure because metrical-structure assignment is intrinsically ordered first.

The utility of HS is not limited to the phenomena discussed here. In other work, I apply it to additional problems in language typology: limitations on the use of global changes to achieve local markedness improvements (McCarthy 2007b), and the coda/onset asymmetry in consonant cluster reduction and place assimilation

(McCarthy 2008). In general, it is relevant in any situation where linguistic patterns are best understood through a gradual ascent to optimality.

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