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An Introduction to Harmonic Serialism

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Abstract

Harmonic Serialism is a derivational version of Optimality Theory. This article describes the principles of Harmonic Serialism and the arguments for it. Evidence is drawn from the typology and other properties of various phonological phenomena: stress, syncope, assimilation, and positional neutralization.

1. *Introduction*

A generative grammar is a mapping between two levels of representation. Is this mapping direct or indirect? A common answer in both phonology and syntax is that the mapping is indirect: there are intermediate steps in a derivation. In Optimality Theory (OT), however, the standard answer to date has been that the mapping is direct (Prince and Smolensky 1993/2004). Parallel OT, as I will refer to this theory, relates underlying and surface representations without intermediate steps.

Because parallel OT is a direct-mapping theory, its candidate-generating component GEN must be capable of changing the underlying form in multiple ways simultaneously. Parallel OT's candidate sets are consequently large and diverse (infinite, in fact). Winning candidates are chosen by the evaluation component EVAL, which applies a language-particular constraint hierarchy to choose the optimal candidate as the surface form.

The central insight into OT – candidate comparison by a hierarchy of ranked, violable constraints – is not necessarily tied to the direct-mapping architecture, however. A version of OT with indirect mapping is known as *Harmonic Serialism* (HS). It is in most respects similar to parallel OT, except that it posits serial derivations with intermediate steps. This single change has important empirical consequences that come down on the side of HS.

This article explains HS and some of its principal results. It begins (Section 2) with an explanation of HS's basic architecture and some properties that follow from it. It continues with two main types of argument for HS, the need for representations intermediate between underlying and surface (Section 3) and HS's desirable consequences for language typology (Section 4). Section 5 concludes.

2. *Structure of the Theory*

2.1. BASIC PRINCIPLES

There are two related differences between HS and parallel OT. First, HS's GEN is limited in how extensively it can change the input when it constructs a candidate set. This property of HS's GEN is known as *gradualness*, alluding to its effect on derivations. Second, after each evaluation, the optimal candidate selected by EVAL is fed back into GEN as a new input, from which a new candidate is constructed. This GEN-*EVAL loop* continues until there is *convergence*, when the optimum chosen by EVAL is identical to the most recent input to GEN. At that point, the derivation terminates, and the convergent form is the final output of the grammar.

Exactly how to define gradualness is a topic of ongoing research, often discussed in the HS work cited later. The intuition is that HS's GEN can make only one change at a time; for example, from input /pat/ it can construct candidates like *pati* (one epenthesis) or *pa* (one deletion), but not *ipati* (two epentheses), *a* (two deletions), or *ati* (one of each). Another way of saying the same thing is that GEN consists of a list of operations, and GEN produces unfaithful candidates that differ from its input by a single application of one of these operations. The open research question concerns the details of these operations. Although a complete answer is not yet possible, the logic of how to answer this question is clear (see McCarthy 2010).

2.2. ILLUSTRATION

The following example is intended to offer a simple illustration of HS, although not an argument for it. (The arguments will come later.)

In Classical Arabic, word-initial consonant clusters are prohibited. When they occur in underlying representations, glottal stop and a high vowel are preposed: /fʕal/ → *ʔifʕal* 'do!'. Under the assumption that GEN can insert only one segment at a time, two steps are required before convergence: /fʕal/ → *ifʕal* → *ʔifʕal*. At step 1, the input to GEN is the underlying form /fʕal/, and the candidate set includes faithful *fʕal* as well as all of the ways of making a single change in it: *ifʕal*, *ʕal*, *fal*, *fʕil*, *fril*, etc. These candidates are evaluated (see tableau (1)), and the optimal one, *ifʕal*, becomes the new input to GEN at step 2.

(1) Step 1 of /fʕal/ → *ʔifʕal*[1]

	/fʕal/	*COMPLEX-ONSET	MAX	ONSET	DEP
a. →	ifʕal			*	*
b.	fʕal	*!			
c.	fal		*!		
	etc.				

The candidate set at step 2 includes faithful *ifʕal* as well as *ʔifʕal*, *ifʕali*, *fʕal* (with deletion of the previously epenthesized vowel), etc. Tableau (2) shows that the grammar chooses *ʔifʕal*, which becomes the new input to GEN at step 3:

(2) Step 2 of /fʕal/ → *ʔifʕal*

	ifʕal	*COMPLEX-ONSET	MAX	ONSET	DEP
a. →	ʔifʕal				*
b.	ifʕal			*!	
c.	fʕal	*!	*!		
	etc.				

At step 3 (tableau (3)), the input and optimum are both *ʔifʕal*. The derivation has therefore converged on *ʔifʕal* as the final output of the grammar:

(3) Step 3 of /fʕal/ → *ʔifʕal*

ʔifʕal	*COMPLEX-ONSET	MAX	ONSET	DEP
a. → ʔifʕal				
b. ifʕal		*!	*	
c. ʔifʕali				*!
etc.				

2.3. CONSEQUENCES OF THE BASIC PRINCIPLES

Various empirical and formal consequences derive from these assumptions about HS's architecture when combined with all of the properties it shares with parallel OT. The empirical consequences will be discussed in later sections; we will focus on some formal ones now.

2.3.1. Harmonic Improvement

HS derivations must show *monotonic harmonic improvement*. Harmony is what OT grammars select for: A is more harmonic than B if and only if the highest ranking constraint that differentiates A and B is one that assigns fewer violation to A than to B. In any HS derivation $i_1 \rightarrow i_2 \rightarrow \ldots \rightarrow i_n \rightarrow i_n$, harmony improves steadily until the $i_n \rightarrow i_n$ convergence step, when harmony remains unchanged. Monotonic harmonic improvement is necessary because GEN always includes its unchanged input among the candidates that it generates, so every i_j has to be the winner of a competition that includes i_{j-1} as a competitor. Thus, i_j has to be more harmonic than i_{j-1}, which has to be more harmonic than i_{j-2}, and so on. In the derivation (1–3), for example, *ʔifʕal* is more harmonic than *ifʕal*, which is more harmonic than *fʕal*.

Harmonic improvement may require constraint rankings that are not necessary in a parallel OT analysis of the same data with the same constraints. Tableau (1) is a case in point. For *ifʕal* to be more harmonic than *fʕal*, *COMPLEX-ONSET has to dominate ONSET. In a parallel OT analysis, that ranking is not needed. Rather, *COMPLEX-ONSET and ONSET are unranked with respect to one another because both are undominated, as every surface form of the language obeys them.[2]

The stricter ranking requirements that HS analyses have to meet because of harmonic improvement might sound like a liability, but in fact they are an asset. They are the basis for some of the typological arguments for HS.

2.3.2. Finiteness

Because HS derivations must show monotonic harmonic improvement, they are guaranteed to converge in a finite number of steps. Under the standard OT assumption that all constraints either evaluate outputs (markedness) or require input–output identity (faithfulness), harmony cannot improve without limit (Moreton 2000, 2003).

Because of the gradualness requirement on GEN, HS's candidate sets are finite as well. Finiteness is assured under the assumption that GEN contains no intrinsically iterative or recursive operations. This means that the effects of iteration or recursion have to be obtained by multiple passes through the GEN-EVAL loop.

2.3.3. Constraints

Although HS's basic premises say nothing about constraints, the difference between HS's and parallel OT's architectures can have consequences for the viability, or at least the usefulness, of certain constraint types.

Faithfulness is one locus of difference. The natural hypothesis in HS is that faithfulness constraints refer to the input to the current derivational step, rather than the underlying representation. This hypothesis has consequences for the formulation of positional faithfulness constraints (see Section 3). Together with gradualness, it also limits the value of local conjunction of faithfulness constraints (Kirchner 1996; Moreton and Smolensky 2002).[3]

Markedness constraints may also differ in their effects and viability between HS and parallel OT. For example, Pater (forthcoming) shows that a type of scalar constraint that is problematic in parallel OT performs as intended in HS. On the other hand, Kathryn Pruitt and Magnolia Mutuc have shown in unpublished work that *Lapse produces implausible results in HS but not parallel OT. A lapse is a pair of adjacent unstressed syllables, such as *x́***xx***x́*. When all stresses can be assigned at once, the optimal way of satisfying *Lapse is an alternating pattern (Kager 2001; McCarthy 2003): /xxxxxx/ → *x́xx́xx́x* or *xx́xx́xx́*. But when stresses have to be assigned one at a time, the results are not nearly so well behaved. At step 1 from /xxxxxx/, for instance, *xx́xxxx* is a possible winner, and it can change into *xx́xxx́x* at step 2 while still satisfying *Lapse at least as well as any other candidate.

2.4. Provenance and Relation to Other Theories

Despite these differences, it should be clear that HS is really just a version of OT rather than a full-blown alternative to it. Indeed, HS was first mentioned in OT's *locus classicus*, Prince and Smolensky (1993/2004), but it was not pursued there and was in fact rejected in favor of parallel OT. The case for HS was reopened in McCarthy (2000, 2002): 159–63, McCarthy (2007b), where some general consequences of this theory are identified and discussed. These and subsequent developments are the topic of Sections 3 and 4.

HS is distinct from, though related to, OT with candidate chains (OT-CC), in which an HS-like system is used to construct derivations that then compete against one another (McCarthy 2007a; Wolf 2008). Other efforts to implement OT with derivations should also be mentioned (Black 1993; Chen 1999; Kiparsky 2000; Rubach 2000; Norton 2003), as well as two non-OT theories of derivational constraint satisfaction, Harmonic Phonology (Goldsmith 1990, 1993) and the Theory of Constraints and Repair Strategies (Paradis 1988a,b).

It is often asked how HS differs from rule-based phonology (RBP) in the tradition of Chomsky and Halle (1968). It would be better to ask how they are alike, because there are many differences and few similarities. In fact, there are just two shared properties: both theories posit derivations with intermediate representations, and both place limits on how much can change from one step of a derivation to the next.[4] The differences consist of all of the other ways that OT differs from RBP: in RBP, a grammar is a list of language-particular rules; in OT, a grammar is a ranking of universal constraints; in RBP, rules change one representation into another; in OT, constraints compare candidates; and so on. All of the arguments that support OT over RBP (e.g., McCarthy 2002: 66–138), other than arguments from parallelism, apply with equal force to HS.

3. *Evidence for Intermediate Forms*

The existence of intermediate derivational steps is one of the two characteristics of HS that distinguish it from parallel OT. In this section, I briefly summarize two arguments for HS that are based on this difference. Several others are noted at the end of the section. These arguments share a common premise: certain generalizations cannot be expressed in underlying or surface representation, but those are the only two levels of representation that parallel OT has. These generalizations are expressible in HS's intermediate representations, however.

The first argument comes from McCarthy (2008c). In many languages, some or all unstressed vowels delete. This simple generalization proves to be difficult to express in a parallel OT analysis. The problem is that the generalization is inherently derivational: stress is assigned and then unstressed vowels are deleted. A parallel OT grammar must optimize the effects of stress assignment and syncope simultaneously, and this turns out to be inadequate both descriptively and typologically. But because HS is a derivational theory, this generalization is unproblematic.

In Macushi Carib (Hawkins 1950: 87), for example, words are parsed into iambic feet from left to right, and only then are unstressed vowels deleted:[5]

(4) Stress–syncope interaction in Macushi Carib

Underlying	Stress	Syncope	
piripi	(pirí)(pí)	(prí)(pí)	'spindle'
wanamari	(waná)(marí)	(wná)(mrí)	'mirror'
u-manari-rɨ	(umá)(narí)(rɨ́)	(má)(nrí)(rɨ́)	'my cassava grater'
u-wanamari-rɨ	(uwá)(namá)(rirɨ́)	(wá)(nmá)(rrɨ́)	'my mirror'

In HS, these are exactly the steps that the derivation follows. Because of gradualness, stress assignment and syncope cannot occur simultaneously. Stress assignment occurs first because syncope is *intrinsically ordered* after stress. Two processes are said to be intrinsically ordered if the applicability of one depends on the prior application of the other. In HS, this occurs when the markedness constraint implicated in the second process is not violated until the first process has applied. In the case of syncope and stress, the markedness constraint that is responsible for syncope, *V-Place$_{weak}$, is violated by a vowel in the weak syllable of a foot. (In other words, vowel place features are not licensed in this weak position.) Before foot structure has been assigned, all vowels vacuously satisfy this constraint. Therefore, *V-Place$_{weak}$ is not active until stress has been assigned, so stress is intrinsically ordered before syncope.

Let us assume that Gen includes operations that create a foot, remove a foot, or delete a vowel. This assumption about gradualness means that the candidate set at step 1, shown in tableau (5), includes candidates with foot parsing or syncope but not both. The imperative to parse is provided by the constraint Parse-Syllable, which is violated by any unfooted syllable.

(5) Step 1 of /wanamari/ → *(wná)(mrí)*

wanamari	Parse-Syllable	*V-Place$_{weak}$	Max
a. → (waná)mari	**	*	
b. wanamari	****!		
c. wanmari	***!		*

Tableau (5) shows how stress assignment is intrinsically ordered before syncope. Syncope prior to foot parsing, as in (5c), violates MAX pointlessly, because *V-PLACE$_{weak}$ is vacuously satisfied by unfooted vowels. Indeed, because foot parsing introduces a violation of *V-PLACE$_{weak}$, as in (5a), the foot-parsing imperative PARSE-SYLLABLE must be ranked higher or else footless (5b) would win.[6]

At step 2, satisfaction of PARSE-SYLLABLE is still the prime directive, so syncope is once again postponed:

(6) Step 2 of /wanamari/ → *(wná)(mrí)*

wanamari	PARSE-SYLLABLE	*V-PLACE$_{weak}$	MAX
a. → (waná)(marí)		**	
b. (waná)mari	**!	*	
c. (wná)mari	**!		*
d. (waná)mri	*!	*	*

In a word of this size, full satisfaction of PARSE-SYLLABLE has been achieved by the end of step 2, so it is finally possible to attend to the requirements of *V-PLACE$_{weak}$, which is the next markedness constraint in the ranking. One of the unstressed, footed vowels deletes at step 3, with the other deleting at step 4 (not shown).

(7) Step 3 of /wanamari/ → *(wná)(mrí)*

(waná)(marí)	PARSE-SYLLABLE	*V-PLACE$_{weak}$	MAX
a. → (wná)(marí)		*	*
b. (waná)(marí)		**!	

Which vowel deletes first is unimportant, because ultimately both delete. As it happens, the constraint responsible for left-to-right foot parsing, ALIGN-L(foot, word), also favors deleting from left to right – hence *(wná)(marí)* rather than *(waná)(mrí)* is shown as the winner in (7).

Finally, the derivation converges at step 5, with input and winner identical to one another. Alternatives to the intended winner, such as those in (8b) and (8c), reintroduce violations of the top-ranked markedness constraints or violate faithfulness constraints gratuitously:

(8) Step 5 of /wanamari/ → *(wná)(mrí)* – Convergence

(wná)(mrí)	PARSE-SYLLABLE	*V-PLACE$_{weak}$	MAX
a. → (wná)(mrí)			
b. wna(mrí)	*!		
c. (wnmrí)			*!

This analysis shows that HS offers a viable approach to stress–syncope interactions. Parallel OT does not. The problem is that parallel OT lacks the intermediate representation in which stress has been assigned prior to syncope. The parallel OT analysis must therefore distinguish the intended winners from losing candidates that never even arise in the HS analysis, and this proves to be impossible. Here are some examples:

(9) Problematic losers in parallel OT

Underlying	Intended winner	Problematic losers
piripi	(prí)(pí)	(pí)(rpí)
wanamari	(wná)(mrí)	(wá)(nmá)(rí)
u-manari-rɨ	(má)(nrí)(rɨ́)	(ú)(mná)(rrɨ́)
u-wanamari-rɨ	(wá)(nmá)(rrɨ́)	(ú)(wná)(mrí)(rɨ́)

The intended winners respect the generalization that syncope affects the odd-numbered non-final syllables – i.e., exactly the syllables that are left unstressed after the left-to-right iambic parse. The problematic losers follow the generalization that syncope affects the *even*-numbered non-final syllables – i.e., exactly the syllables that would be left unstressed by a left-to-right *trochaic* parse. The problem for parallel OT is that no markedness constraint evaluating surface forms can systematically distinguish the two patterns of syncope. The reason for this failure is that parallel OT has only two levels of representation to work with, underlying and surface, but capturing the generalization about which vowels are targeted for syncope requires an intermediate level, post-stress and pre-syncope.

Another argument for HS's intermediate levels of representation comes from Jesney (forthcoming). Positional faithfulness constraints are like other faithfulness constraints except that their scope of action is limited to certain prominent positions, such as stressed syllables (Beckman 1998). For example, the positional faithfulness constraint $\text{I}{\scriptstyle\text{DENT}}_{\text{stress}}$(nasal) is protective of nasalization contrasts in stressed syllables. When ranked above $^*\text{V}_{\text{nasal}}$, which itself dominates the position-insensitive faithfulness constraint IDENT(nasal), the result is a language like Nancowry (Radhakrishnan 1981), where phonemic vowel nasalization is maintained in stressed syllables but neutralized in unstressed ones. In the following schematized example, stress is assumed to be trochaic, so TROCHEE is undominated:

(10) Attested positional faithfulness effect (parallel OT)

bãdõ	$\text{IDENT}_{\text{stress}}$(nasal)	PARSE-SYLL	TROCHEE	$^*\text{V}_{\text{nasal}}$	IDENT(nasal)
a. → (bã́do)				*	*
b. (bádo)	*!				**
c. (bã́dõ)				**!	
d. (badṍ)			*!	*	*
e. bado		**!			**

Because of $^*\text{V}_{\text{nasal}}$, nasalized vowels are neutralized to oral in unstressed syllables, as in (10a). But there is no neutralization in stressed syllables (cf. (10b)), because of $\text{IDENT}_{\text{stress}}$(nasal).

Parallel OT's problem, which was first recognized by Rolf Noyer [cited in Beckman (1998: fn. 37)], is that positional faithfulness constraints work as intended only when the position of greater faithfulness is held constant in those candidates where the positional faithfulness constraint is making a crucial comparison. That is certainly true in (10): the surface reflex of /ã/ is stressed in both (10a) and (10b). Candidates that are stressed differently or not at all, such as (10d) and (10e), are ruled out by other constraints, so they do not depend on IDENT$_{stress}$(nasal) to exclude them.

Now consider what happens when stress is allowed to differ among the viable candidates. In (11), TROCHEE is ranked below *V$_{nasal}$. The result is that stress is shifted from an underlying nasalized vowel onto an underlying oral one. This happens because the positional faithfulness constraint is crucially comparing two candidates, (11a) and (11b), that differ in stress:

(11) Unattested positional faithfulness effect (parallel OT)

/pãko/	IDENT$_{stress}$(nasal)	PARSE-SYLL	*V$_{nasal}$	IDENT(nasal)	TROCHEE
a. → (pakó)				*	*
b. (páko)	*!			*	
c. (pã́ko)			*!		
d. pako		**!		*	

When this same grammar is presented with any other combination of nasalized and oral vowels (i.e., /bãdõ/, /sato/, or /kafõ/), it defaults to trochaic stress. Thus, in this hypothetical language, stress is normally on the penult, but it is on the ultima when the penult vowel is underlying nasal and the final vowel is underlying oral, though both end up oral at the surface. No real language does anything remotely like this.

What is the source of this problem? Positional faithfulness constraints are sensitive to structure that is assigned by the grammar, such as stress. Because the surface form is the only grammar-derived level of representation in parallel OT, its positional faithfulness constraints have to be defined like this: 'If a segment in the surface representation is in a stressed syllable, it must be faithful to its underlying correspondent'. When positional faithfulness constraints are defined in this way, the problem in (11) is unavoidable.

As Jesney shows, this otherwise intractable problem is solved if HS is adopted and if positional faithfulness constraints are defined to refer to the prosodic structure of the *input*: 'If a segment in the input to GEN is in a stressed syllable, it must be faithful to its underlying correspondent'. In HS, the input to GEN is not necessarily the underlying representation, so it can have structure that has been assigned by the grammar. Because the input is the same for all candidates being compared, problems like (11) cannot arise.

The HS derivation of /pãko/ proceeds as follows. At step 1, there is a choice between assigning stress and denasalizing *ã*. If *V$_{nasal}$ dominates PARSE-SYLLABLE, then denasalization takes precedence, and we have a language without a positional faithfulness effect. If PARSE-SYLLABLE is ranked higher, as in tableau (12), then stress is assigned first. Stress (re)assignment and denasalization cannot co-occur, of course, because of gradualness.

(12) Step 1 from /pãko/

/pãko/	IDENT$_{stress}$(nasal)	PARSE-SYLLABLE	*V$_{nasal}$	IDENT(nasal)	TROCHEE
a. → (pã́ko)			*		
b. pako		**!		*	
c. (pãkó)			*		*!

The derivation then converges at step 2, shown in (13). Input *(pã́ko)* has a stressed nasalized vowel. Because this vowel is stressed in the input to this pass through the GEN-EVAL loop, redefined $\text{IDENT}_{\text{stress}}$(nasal) protects it from denasalization:

(13) Step 2 from /pãko/

(pã́ko)	$\text{IDENT}_{\text{stress}}$(nasal)	PARSE-SYLLABLE	$*V_{nasal}$	IDENT(nasal)	TROCHEE
a. → (pã́ko)			*		
b. (páko)	*!			*	
c. (pãkó)			*		*!

The failure of the final-stressed candidate *(pãkó)* in (12c) and (13c) is crucial to this argument for HS. If this candidate were to survive, it would change into *(pakó)* at the next step of the derivation, and HS would be making the same bad prediction as parallel OT. In fact, it does not, and here is the reason why:

- The parallel OT tableau (11) shows that *(pakó)* is the *global optimum* for underlying /pãko/ under this grammar. Another way of saying the same thing is that *(pakó)* is the *global minimum of potential for harmonic improvement*.
- The derivation (12–13) shows that this global optimum is inaccessible in HS because there is no harmonically improving path to it. The HS derivation gets stuck at a *local optimum*, *(pã́ko)*. Equivalently, *(pã́ko)* is a *local minimum of potential for harmonic improvement*.
- This happens because HS's GEN cannot simultaneously assign final stress and denasalize the penult, and final stress is not harmonically improving unless the penult is simultaneously denasalized.

The overall lesson here is that HS has no look-ahead capability; a candidate that fails to improve harmony at step *n* cannot win simply because it would lead to greater harmonic improvement at step *n + 1*. 'Getting stuck' at a local optimum sounds like a bad outcome, but it is actually a good one. Positional faithfulness and other typological results of HS (section 4) depend on this property of the theory.

The examples of stress–syncope interaction and positional faithfulness show that HS's intermediate levels of representation are necessary to capture some basic generalizations about phonology. Other arguments for HS's intermediate levels are based on discussions of opacity (Elfner 2009), phonetically grounded constraints (McCarthy 2011), scalar constraints (Pater forthcoming), and local variation (Kimper forthcoming).

4. *Evidence from Language Typology*

Language typology is a central concern of research in OT. Because the same constraints can be ranked differently in different languages, any proposed constraint system constitutes an implicit claim about the range of permissible variation among languages. The logic of language typology in HS is explained in McCarthy (2007b, 2010) and summarized here.

For identical constraint systems, parallel OT and HS may predict different typologies. The source of the difference is HS's core properties, gradualness and harmonic improvement. Does a given constraint system CON yield a language in which underlying /

A/maps to surface *B*? In parallel OT, the answer is yes if and only if there is some ranking of Con where *B* is more harmonic than *A* and every other candidate derived from /A/. In HS, this answer is sufficient only if *B* and /A/differ by a single change. If it requires more than one change to get from /A/to *B*, then there must also be a harmonically improving path of winning intermediate steps from /A/to *B*. Sometimes, there is no such path. That is when parallel OT and HS make different typological predictions.

This reasoning is important in HS's solution to some *too many repairs* (TMR) problems. A TMR problem is the observation that the actually attested ways of satisfying a markedness constraint are often more limited than we would expect from ranking permutation (Blumenfeld 2006; Lombardi 2001; Pater 1999; Steriade 2001/2008; Wilson 2001; and others). For example, the markedness constraint Coda-Cond says that coda consonants do not license place of articulation (Ito 1989; Goldsmith 1990: 123–28). One way of satisfying this constraint is for a coda to share place with a following onset, because onset position does license place. This is the reason why place often assimilates in consonant clusters: in *pamta*, labial place is unlicensed in coda *m*, but in *pa͡nta* the *n*'s coronal place is licensed because it is shared with the onset (as indicated by the ligature). Unexplained is why place always assimilates from the onset to the coda and never the other way around: /pamta/ → *pa͡nta*, never *pa͡mpa*. Tableau (14) illustrates the problem:

(14) /pamta/ → *pa͡nta* /*pa͡mpa* in parallel OT

/pamta/	Coda-Cond	Ident(place)
a. → pa͡nta		*
b. → pa͡mpa		*
c. pamta	*!	

Parallel OT predicts intra- or interlinguistic variation in direction of assimilation when violations of Coda-Cond are repaired, but the predicted variation is not observed.

HS offers an explanation for this asymmetry, once the process of place assimilation is properly understood in operational terms (McCarthy 2008b). Long before HS or even OT, it was claimed that place assimilation is a two-step process, with deletion of the unlicensed place feature prior to spreading of the licensed one (Poser 1982; Mascaró 1987; Cho 1990; Kiparsky 1993): /pamta/ → *paNta* → *pa͡nta*. (N denotes a placeless nasal.) If HS's Gen is restricted in this fashion, then the directional asymmetry in place assimilation follows automatically. At step 1, deletion of place from the coda consonant satisfies Coda-Cond, but deletion of place from the onset (yielding a placeless *ʔ*) does not:

(15) Step 1 of /pamta/ → *pa͡nta*

/pamta/	Coda-Cond	Have-Place	Ident(place)
a. → paNta		*	*
b. pamta	*!		
c. pamʔa	*!	*	*

At step 2, placeless *N* becomes *n* by spreading place from the following *t*. This occurs to satisfy HAVE-PLACE, which *N* violates:

(16) Step 2 of /pamta/ → *pant͡a*

paNta	CODA-COND	HAVE-PLACE	IDENT(place)
a. → pant͡a			*
b. paNta		*!	

The derivation then converges at step 3 (not shown).

This example illustrates the point about harmonic improvement that was made earlier in this section. In parallel OT, *pant͡a* and *pamp͡a* are both possible surface results from underlying /pamta/, because both satisfy CODA-COND and violate IDENT(place) equally. In HS, though, it is not enough for a surface form to be a parallel OT winner; it must also be linked with the underlying form by a chain of harmonically improving intermediate forms. That is not the case with *pamp͡a*; under the stated assumption about GEN, it requires an intermediate form, *pamʔa*, that does not improve harmony relative to CODA-COND, as (15) shows. Because of gradualness and harmonic improvement, HS yields a more restrictive typology of place assimilation than parallel OT does, all else being equal. This more restrictive typology better fits what we actually find in languages.

Another area where HS appears to have a typological advantage over parallel OT is in accounting for locality effects. For example, Pruitt (2008) shows that metrical foot parsing exhibits locality effects that are hard to account for in parallel OT but follow readily in HS from the assumption that GEN builds feet one at a time.

One such locality effect involves the interaction between foot parsing and vowel shortening. In quantity-sensitive languages, trochaic feet are usually limited to a pair of light syllables (ĹL) or a single heavy syllable (H́) (Hayes 1985, 1995; McCarthy and Prince 1986/1996; Prince 1990). (H́L) trochees are disfavored by a constraint called FOOT-FORM. In the following discussion, we will assume a language with such feet and with left-to-right foot parsing.

The standard ranking for left-to-right foot parsing uses the constraint ALIGN-L(foot, word) to favor having all feet as far to the left as possible:

(17) Left-to-right parsing (parallel OT)

salamataka	FOOT-BINARITY	PARSE-SYLLABLE	ALIGN-L (foot, word)	ALIGN-R (foot, word)
a. → (sála)(máta)ka		*	**	****
b. salamataka		*****!		
c. sa(láma)(táka)		*	****!	**
d. (sála)(máta)(ká)	*!		******	****

If we include FOOT-FORM at the top of the hierarchy and allow shortening of long vowels by ranking IDENT(long) low, we get a language in which a long vowel in the first syllable is shortened only if it is followed by an odd number of light syllables. Compare (18) with (19):

(18) Shortening before odd L sequence (parallel OT)

pa:takasa	FOOT-BINARITY	FOOT-FORM	PARSE-SYLLABLE	ALIGN-L (foot, word)	IDENT (long)
a. → (páta)(kása)				**	*
b. (pá:)(táka)sa			*!	*	
c. (pá:ta)(kása)		*!		**	

(19) No shortening before even L sequence (parallel OT)

pa:takasafa	FOOT-BINARITY	FOOT-FORM	PARSE-SYLLABLE	ALIGN-L (foot, word)	IDENT (long)
a. → (pá:)(táka)(sáfa)				****	
b. (páta)(kása)fa			*!	**	*
c. (pá:ta)(kása)fa		*!		**	

No known language behaves in this highly non-local fashion, where avoiding an unfooted syllable at one end of the word, as in (18b), triggers vowel shortening at the other end of the word. Optimizing metrical structure can cause vowels to shorten, as it does in Latin (Allen 1973; Prince and Smolensky 1993/2004; Mester 1994) or Fijian (Schütz 1985; Dixon 1988; Hayes 1995), but these effects are always strictly local, involving a pair of adjacent syllables.

This example reflects a more general problem with parallel OT, highlighted in McCarthy (2007b, 2008c, forthcoming) and Pruitt (2008): it has excessive power to do global optimization. The reason why (17–19) constitutes a possible language in parallel OT is that its GEN builds complete and final surface candidates in which the effects of vowel shortening and full metrical parsing are present together. Thus, EVAL gets to choose the best combination of shortening and parsing, no matter how distant the long vowel might be from the parsing problem.

In HS, if GEN is limited to building one foot at a time, then the language in (17–19) cannot be obtained with these constraints, as Pruitt (2008) demonstrates. To begin with, we consider how iterative parsing works in HS with a word that contains no heavy syllables. At step 1 (tableau (20)), the best option is to build a disyllabic foot at the left edge of the word. Building no foot or a monosyllabic foot is disfavored by PARSE-SYLLABLE; the latter also violates FOOT-BINARITY. Building a foot non-initially violates ALIGN-L(foot, word):

(20) Step 1 of iterative parse

/salamataka/	FOOT-BINARITY	PARSE-SYLLABLE	ALIGN-L (foot, word)	ALIGN-R (foot, word)
a. → (sála)mataka		***		***
b. salamataka		*****!		
c. sa(láma)taka		***	*!	**
d. salama(táka)		***	***!	

At step 2 (tableau (21)), the best option is to build a disyllabic foot as far to the left as possible. PARSE-SYLLABLE requires construction of an additional foot, and ALIGN-L determines where it is built. After this, the derivation converges, as tableau (22) shows. The only remaining unfooted syllable is the last one, and FOOT-BINARITY ensures that nothing can be done about it.

(21) Step 2 of iterative parse

(sála)mataka	FOOT-BINARITY	PARSE-SYLLABLE	ALIGN-L (foot, word)	ALIGN-R (foot, word)
a. → (sála)(máta)ka		*	**	****
b. (sála)mataka		***!		***
c. (sála)ma(táka)		*	***!	***

(22) Step 3 of iterative parse (convergence)

(sála)(máta)ka	FOOT-BINARITY	PARSE-SYLLABLE	ALIGN-L (foot, word)	ALIGN-R (foot, word)
a. → (sála)(máta)ka		*	**	****
b. (sála)(máta)(ká)	*!		******	****

What happens when the underlying representation contains an initial long vowel? If we apply the same ranking as (18) and (19), but within the HS architecture, the result does not depend on whether the long vowel is followed by an odd number (23) or even number (24) of light syllables: the leftmost pair of light syllables is parsed into a foot, because this option best satisfies PARSE-SYLLABLE and ALIGN-L(foot, word):

(23) Step 1 from /paːtakasa/(odd sequence of Ls)

/paːtakasa/	FOOT-BINARITY	FOOT-FORM	PARSE-SYLLABLE	ALIGN-L (foot, word)	IDENT (long)
a. → paː(táka)sa			**	*	
b. paːtakasa			****!		
c. (páː)takasa			***!		
d. (páːta)kasa		*!	**		
e. patakasa			****!		*

(24) Step 1 from /paːtakasafa/(even sequence of Ls)

/paːtakasafa/	FOOT-BINARITY	FOOT-FORM	PARSE-SYLLABLE	ALIGN-L (foot, word)	IDENT (long)
a. → paː(táka)safa			***	*	
b. paːtakasafa			*****!		
c. (páː)takasafa			****!		
d. (páːta)kasafa		*!	***		
e. patakasafa			*****!		*

These derivations continue, parsing pairs of light syllables from left to right, and then returning to parse the initial heavy syllable into a foot of its own. The derivations converge on *(páː)(táka)sa* and *(páː)(táka)(sáfa)*. With this ranking, there is no shortening, and there is certainly no dependency of shortening on whether an odd or even number of light syllables follow.

There will be shortening if the ranking of FOOT-FORM and ALIGN-L(foot, word) is reversed, but still there is no dependency of shortening on the following syllables. At step 1, the first two syllables are parsed into a FOOT-FORM-violating foot: *(páːta)kasa*, *(páːta)-kasafa*. Foot parsing continues at step 2, yielding *(páːta)(kása)* and *(páːta)(kása)fa*. At this point, PARSE-SYLLABLE is as well satisfied as it can get, and FOOT-FORM gets its chance to compel shortening of the long vowel, but both the odd and even length words are affected.

This is another clear point of difference between parallel OT and HS. Because parallel OT optimizes globally, it allows long-distance dependencies like the relationship seen in (17–19). HS does not permit this dependency, at least with the standard constraints and the unremarkable version of GEN that we have been assuming. HS is more limited in this respect because decisions about foot parsing and shortening are made one at a time.

This example hints at an important connection between locality and serialism. Long-distance effects are often produced by iterative application of a process; the construction of metrical feet is one example, and successive cyclic *wh*-movement (Chomsky 1977) is another. In parallel OT, process iteration is invisible to EVAL because it takes place entirely in GEN. EVAL sees only the final result. In HS, however, process iteration is visible to EVAL because the results of each iteration are presented in the candidate set. This enforces a kind of locality because each iteration must improve harmony or the process terminates (McCarthy 2007b, 2008c, forthcoming; Pruitt 2008). The claim implicit in HS (and in successive cyclic *wh*-movement) is that visible iteration and its concomitant locality effects are a better theory of language typology than the global alternative.

The study of language typology in HS is still at an early stage. Besides the papers already mentioned, there has been work on typology in relation to autosegmental spreading (McCarthy 2007b, forthcoming), apocope and metathesis (McCarthy 2007b), lexical structure (McCarthy and Pruitt forthcoming), and reduplication (McCarthy et al. 2010). Future research on typology in HS will be greatly aided by the typology calculator OT-Help 2 (Staubs et al. 2009). OT-Help determines all of the possible HS derivations from a given set of inputs and constraints. It generates its own candidates and applies constraints to them, using operations and constraints that are user-defined and fully extensible. OT-Help is currently limited to string representations, but richer structure will be supported in a future release.

5. Concluding Remarks

We have seen reasons to think that HS is superior to parallel OT. Is there evidence that points in the other direction? The earlier OT literature attributes several results to parallelism, but many of these arguments have been questioned in later work. See, for example, responses to Prince and Smolensky's Tongan (1993/2004: 33–38) and Berber (1993/2004: 94–97) arguments in McCarthy (2008c) and Pater (forthcoming), respectively.

What challenges does HS face? Any remaining arguments for parallelism need to be addressed, of course. There also needs to be a serious effort to identify analyses that appear to require intermediate steps that do not improve harmony. For example, Walker (2010) identifies a possible case involving harmony, though Kimper (2010) shows that an HS analysis of Walker's material is possible.

Where will HS go next? Several areas seem particularly likely to lead to interesting results: the phonology–morphology interface, building on Wolf's (2008) work in the OT-CC framework; phonological opacity, which has been discussed in HS terms in McCarthy (2000) and Elfner (2009); and the phonetics–phonology interface, touched on in McCarthy (2011). But perhaps the most important open question is one that was raised in section 2: what are the details of GEN? This question is intimately connected with the study of typology in HS. As one wit suggested, OT is hard, but HS makes it even harder. In parallel OT, typology follows from hypotheses about the constraint set. In HS, typology follows from a combination of hypotheses about GEN and the constraint set. The results so far suggest that HS is worth this extra effort.

Short Biography

John J. McCarthy is a Distinguished University Professor and Head of the Linguistics Department at the University of Massachusetts Amherst. His research deals with various topics in phonology, prosodic morphology, and Optimality Theory. He is the author or editor of four books about OT: a textbook *Doing Optimality Theory* (Blackwell 2008); a handbook *A Thematic Guide to Optimality Theory* (Cambridge 2002); a monograph *Hidden Generalizations: Phonological Opacity in Optimality Theory* (Equinox 2007); and an anthology *Optimality Theory in Phonology: A Reader* (Blackwell 2004). His articles have appeared in the journals *Phonology*, *Natural Language & Linguistic Theory*, *Language*, and *Linguistic Inquiry*. He received a Guggenheim Fellowship in 1992, was elected to the American Academy of Arts and Sciences in 2005, and won the UMass Amherst Distinguished Teaching Award in 2009.

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Notes

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[1] The candidate *fiʕal* is ruled out by CONTIGUITY (Kenstowicz 1994; McCarthy and Prince 1995, 1999).

[2] Acquiring the ranking of *COMPLEX-ONSET over ONSET is an example of a *hidden structure* learning problem, because the crucial datum – the intermediate optimum *ifʕal* – is not in the primary data. Hidden structure learning problems arise in parallel OT as well (Tesar and Smolensky 2000; Boersma and Pater 2008), and techniques have been proposed for dealing with them. These techniques may prove applicable in HS.

[3] In McCarthy (2008b,c), I assume that faithfulness constraints in HS refer to the underlying representation, but I also observe that the same results could be obtained with faithfulness constraints that refer to the input to the current step. The latter view has become standard in subsequent work in HS.

[4] Limits on how much a single rule can do were a later development in RBP. Examples include Prince's (1983) *Move x* and Archangeli and Pulleyblank's (1994) *Insert path*.

[5] Not shown in (4) are lengthening of stressed vowels and main stress on the final foot.

[6] Other candidates, such as trochaic *(wána)mari* or right-to-left *wana(marí)*, are ruled out by constraints that are standard in the OT literature on stress systems. For textbook treatments, see Kager (1999: 142ff.) or McCarthy (2008a: 183ff.).

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