2012

Implications of Harmonic Serialism for lexical tone association

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1. Introduction

One of the properties of the classic version of Optimality Theory in Prince & Smolensky (1993/2004) is *parallelism*: output candidates may show the effects of several different phonological changes at once. Harmonic Serialism (HS), a version of OT that Prince & Smolensky also briefly consider, is *serial* or *derivational* rather than parallel: output candidates show the effect of only one phonological change at a time, but the winning candidate is run through the grammar again so it can accumulate additional changes.

Although Prince & Smolensky put HS aside and it received little subsequent attention, the case for it was reopened in McCarthy (2000, 2002: 159-163, 2007). In these and other works (see McCarthy (2010) for a summary), two main kinds of evidence for HS have been identified. One is that it permits generalizations to be stated on its intermediate representations, neither underlying nor surface. For example, the cross-linguistically common process of unstressed vowel syncope cannot be analyzed satisfactorily without access to a level of representation at which stress has been assigned but syncope has not yet occurred (McCarthy 2008). The other kind of evidence is typological: the same constraints can predict different language typologies under parallel OT (P-OT) and HS, and in many cases examined so far these differences favor HS. Section 2 presents one such example and McCarthy (2010) cites a number of others in the HS literature.

Of course, an honest exploration of HS's consequences must include a search for potential problems. Most of the existing arguments for parallelism in the OT literature have been addressed (in, e.g., McCarthy 2008, McCarthy et al. 2010, Pater to appear). But new arguments have also emerged. This paper lays out one such argument, based on the phonology of tone in Kikuyu.

Section 3 describes the basic tonal phonology of Kikuyu, summarizing the analysis in Clements & Ford (1979). Section 4 then goes on to explain how this system can be analyzed in HS using standard tone constraints. A key feature of this analysis is the assumption that candidates can be generated by adding or removing at most one association line at a time. The argument for parallelism is presented in section 5. It consists of a demonstration that lexically linked tones disrupt the analysis in HS but not P-OT. The problem for HS is that removing an unwanted lexical tone association is sometimes impossible in Kikuyu-type systems. This problem does not arise in P-OT, where removing unwanted tone associations and inserting better ones take place simultaneously.

What conclusion can we draw from this result? One possibility is that HS is simply wrong and the parallel theory is right. This is not a very attractive option, however, because it disregards the large and growing body of evidence for HS over parallelism. The alternative, which we explore in section 6, is to return to a view that was prevalent in the early days of

[1] We are grateful for comments received from the McCarthy-Pater grant group at UMass Amherst. Thanks to John Goldsmith and David Odden for assistance in understanding the ideas about lexical tone association in early autosegmental phonology discussed in section 6. Thanks to Bert Botma, Jeroen van de Weijer, and an anonymous reviewer for comments on the manuscript.

This research was supported by grant BCS-0813829 from the National Science Foundation to the University of Massachusetts Amherst.

autosegmental phonology: tones are never associated in underlying representation. By ensuring that tone association can proceed monotonically, adding links but never deleting them, this move solves the problem identified in section 5.

Finally, section 7 concludes with some discussion of the convergence between our results and those in McCarthy & Pruitt (to appear), where it is shown that lexical foot structure is also incompatible with HS.

2. Harmonic Serialism

In P-OT, Gen can make many changes at once, and as a result the candidate set is large and diverse. In HS, Gen can make only one change at a time, and as a result the candidate set is small and homogeneous. HS makes up for its impoverished Gen by being derivational: the optimal candidate selected by Eval becomes the input for a new application of Gen. This Gen→Eval→… loop continues until convergence, when the output of Eval is identical with the latest input to Gen. The resulting form is the final output of the grammar.

In HS, much depends on precisely how Gen is defined, and so the study of Gen is one of the most important elements of the HS research program. One of our goals in this chapter is to understand what it means for Gen to make "one change" in autosegmental association lines. Some guidance is provided by restrictive theories of phonological rules, which sought to limit exactly how much a single rule could do. Archangeli & Pulleyblank (1994) define primitive operations INSERT/PATH and DELETE/PATH (a path is an autosegmental association line), and similar ideas are fairly standard in other work on autosegmental phonology. If this proposal is incorporated into HS, it means that Gen includes the operations in (1), but it can only apply them once and one at a time:

(1) Operations on autosegmental association lines in Gen

a. Insertion

```
a
¦
X
```

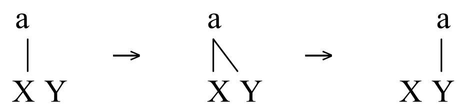
b. Deletion

```
a
╪
X
```

A consequence of this hypothesis is that the process variously referred to as autosegmental shift, displacement, transfer, or flop can never be done in a single step of a HS derivation. In this process, an association line appears to move from one segment or syllable to another. If (1) is right, then moving an association line can only be accomplished by spreading followed by delinking, as in (2):[2]

[2] Another logical possibility is that *a* first delinks from *X* and then reassociates to *Y*. This is not precisely what is meant by autosegmental shift, however. In HS, any grammar that will cause *a* to delink from *X* will do so regardless of whether *Y* follows. The real process, then, is neutralization: *a* delinks from *X*. Aspiration throwback in Sanskrit is an example (Borowsky & Mester 1983): voiced aspirates in coda position lose aspiration, and aspiration reappears on the preceding onset only if it is also a voiced obstruent.

(2) Autosegmental shift, given (1)



Esimbi (Niger-Congo, Cameroon) supplies a nice example (Clements 1991, Hyman 1988, Stallcup 1980, Walker 1997, 2001). In this language, the height of a prefix vowel is determined by the underlying height of the root vowel, and the root vowel neutralizes to [+high]. For example, as shown in (3), the infinitival prefix is a back rounded vowel that alternates among *u*, *o*, and *ɔ*, depending on the underlying vowel of the following root. Hyman and Walker analyze this as a shift process: the height features of the root vowel are transferred to the prefix syllable, and the root vowel becomes high by default.

(3) Esimbi vowel alternations

Underlying root	Infinitive	
/ri/	u-ri	‘to eat’
/zu/	u-zu	‘to kill’
/se/	o-si	‘to laugh’
/to/	o-tu	‘to insult’
/ʤə/	o-ʤɨ	‘to steal’
/rɛ/	o-ri	‘to daub’
/hɔ/	ɔ-hu	‘to knead’
/ba/	ɔ-bɨ	‘to come’

Walker develops a P-OT analysis of Esimbi in which height shifts to the word-initial syllable to satisfy the constraint LICENSE([–high], $_{\mathrm{Wd}}$[σ), which requires any token of a [–high] feature value to be linked to a word-initial syllable (cf. Zoll 2004). Shift is required, rather than spreading, because CRISP(σ, [high]) prohibits any token of the feature [high] from being linked to more than one syllable at a time (cf. Ito & Mester 1999). Ranking these two constraints above IDENT(high), as shown in (4), produces the desired result: [3]

[3] Throughout, we follow Prince (2002) in using comparative tableaux. The winning candidate appears to the right of the arrow, and losers are in the rows below it. Integers stand for the number of violation marks incurred by a candidate, replacing the familiar strings of asterisks. In loser rows, the effects of the constraints are indicated by W and L, W if the constraint favors the winner and L if it favors the loser.

(4) Esimbi in Walker (2001)

/u-ba/ | [–hi, + lo]	LIC([–high], $_{Wd}$[σ])	CRISP(σ, [high])	ID(high)
a. → ɔ-bɨ ╲ [–hi, + lo]			2
b. u-ba | [–hi, + lo]	1 **W**		**L**
c. ɔ-ba ╲| [–hi, + lo]		1 **W**	1 **L**

The full analysis also accounts for why the root vowel defaults to [+high]; see Walker (2001) for details.

An HS analysis in the manner of (2) is nearly identical, the only difference being the ranking of LICENSE above CRISP:

(5) Esimbi in HS, Step 1

/u-ba/ | [–hi, + lo]	LIC([–high], $_{Wd}$[σ])	CRISP(σ, [high])	ID(high)
a. → ɔ-ba ╲| [–hi, + lo]		1	1
b. u-ba | [–hi, + lo]	1 **W**	**L**	**L**

(6) Esimbi in HS, Step 2

ɔ-ba ╲| [–hi, + lo]	LIC([–high], $_{Wd}$[σ])	CRISP(σ, [high])	ID(high)
a. → ɔ-bɨ ╲ [–hi, + lo]			1
b. ɔ-ba ╲| [–hi, + lo]		1 **W**	**L**

At step 3, this derivation converges on the output of step 2 as the final output, because no further improvement in the harmony of *ɔ-bɨ* is possible with this grammar. Observe that faithfulness violations are computed anew at each step, relative to the input to the most recent iteration of GEN.

The P-OT analysis in (4) and the HS analysis in (5)–(6) look quite similar, but there is an important difference between them. In the P-OT analysis, *shifting* [–high] from root to prefix in (4)a competes with *spreading* [–high] from root to prefix in (4)c. In the HS analysis, however, spreading and shift do not compete at step 1. In HS, given our assumptions about GEN, for a feature to shift it must first spread.

As a consequence, HS offers a more restrictive theory of shift processes than P-OT does, all else being equal. It is more restrictive because shift in HS is limited by the same constraints, hard or violable, that limit spreading. These constraints have been studied throughout the history of autosegmental phonology, starting with the Well-Formedness Condition of Goldsmith (1976a, b) and continuing through much more recent proposals about strict locality (Gafos 1999, Ní Chiosáin & Padgett 2001, Walker 1998, and others). In P-OT, there is no reason to expect constraints on spreading to also govern shift. Indeed, it is incumbent on the proponent of P-OT to demonstrate that this less restrictive theory of shift is necessary or to show how constraints on spreading can be non-stipulatively extended to shift.

It is important to realize that the connection between shift and spreading in HS depends on making the assumption about GEN in (1). If GEN also included a more powerful operation that is able to shift an association in a single step, then step 1 of the HS derivation would look exactly like the P-OT tableau in (4). This reflects a general property of HS: analysis and typology depend on assumptions about *both* GEN and CON (McCarthy 2009). This point will be revisited in section 5.

3. Tone association in Kikuyu

In Kikuyu, tone association is fully predictable (Clements 1984, Clements & Ford 1979): the first tone is associated with the first two syllables, and each subsequent tone is associated with the syllable immediately following the morpheme that supplied it.

(7) Example

a. Lexical representations

Segments	Tone	
to	L	'we'
ma	H	'them'
rɔr	L	'look at'
ir-ɛ	H	current past tense

b. Surface form

```
 L   H L H
 |\  | | |
tomarɔrirɛ
```

'we looked at them'

Kikuyu follows this pattern with remarkable regularity (though see Clements 1984: 290, 298 on two non-conforming situations).

In Clements & Ford's (1979) analysis, surface structures like (8) are obtained from underlying representations in which tones are lexically listed with morphemes but not autosegmentally associated with them. The underlying forms of the morphemes in (7) are therefore: /to, L/; /ma, H/; /rɔr, L/; and /ir-ɛ, H/. In the first step of the derivation, a language-particular rule associates the initial L with the *second* syllable:

(8) After initial tone association rule

```
  L   H L H
   \
 tomarɔrirɛ
```

From this point forward, universal tone association conventions take over. They cause the remaining unlinked tones to be linked one-to-one, from left to right, to the toneless syllables:

(9) After one-to-one left-to-right association

```
  L   H L H
   \  | | |
 tomarɔrirɛ
```

The universal tone association conventions also cause the initial L to spread to the toneless initial syllable, yielding the surface form in (7)b.

It sometimes happens that there are as many tones as syllables. Since the first tone takes up two syllables, a tone is left over after one-to-one left-to-right association. One possible disposition of the left-over tone is that it becomes part of a contour tone. Kikuyu allows rising tones on the final syllable, as in (10):

(10) Final rising tone (Clements & Ford 1979: 191)

```
  L  L H           L  L  H
                   |\  \/
 mo-raŋgi   →     moraŋgi          'bamboo'
```

But if the tonal contour is forbidden, then the left-over tone remains floating. For example, Kikuyu does not allow contour tones falling from H to L. As a result, the L tone remains floating in (11), where its presence can be inferred from its role in the downstep system (Clements & Ford 1979: 203ff.):

(11) Final floating tone

```
 L  H L           L H L
                  |\ \
 i-kara     →     ikara            'charcoal'
```

The assumption that tones are lexically unassociated with their sponsoring morphemes is essential to Clements & Ford's analysis. It is precisely because the non-initial tones are unassociated in (8) that the universal tone association conventions produce (9). If, on the contrary, tones were associated in underlying representation, then the immediate output of the initial tone association rule would look like this:

(12) After initial tone association rule, underlying linked tones

```
  L H L H
  |\| | |
 tomarɔrirɛ
```

The universal tone association conventions are no guide through the complex chain of operations that would be needed to get from (12) to the surface form in (7)b. Thus, the assumption that tones are unassociated in underlying representation is doing real work in Clements and Ford's analysis.[4]

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[4] We emphasize this point because non-association of tones in underlying representation is often posited for less weighty reasons, such as considerations of minimal redundancy.

4. Kikuyu tone association in Harmonic Serialism

In the view of Clements and Ford (1979), one-to-one left-to-right association of tones with syllables is the default pattern cross-linguistically. To analyze this pattern in HS (or OT generally), constraints of four types are required:

(i) Constraints against floating tones and toneless syllables, which approximate the effects of Goldsmith's (1976b) Well-formedness Condition for autosegmental phonology. These constraints motivate tone-syllable association.

(13) NO-FLOAT (NO-FL)
Assign one violation mark for every tone that is not associated with a syllable.

(14) HAVE-TONE (HAVE-T)
Assign one violation mark for every syllable that is not associated with a tone.

(ii) Constraints against skipping tones or syllables in the process of association. They ensure that association iterates directionally.

(15) NO-SKIP(tone) (NO-SK(t))
Assign one violation mark for every unlinked tone that is preceded and followed (at any distance) by linked tones.

(16) NO-SKIP(syllable) (NO-SK(s))
Assign one violation mark for every unlinked syllable that is preceded and followed (at any distance) by linked syllables.

(iii) A constraint requiring the initial tone to link to the initial syllable. This accounts for the default left-to-right direction.

(17) LINK-INITIAL (LNK-INIT)
Assign a violation mark if the initial tone is not linked to the initial syllable.

(iv) The faithfulness constraint IDENT(tone), which is violated once for each change in an association line. (Because deletion and insertion of tones are not in general at issue here, we assume that MAX(tone) and DEP(tone) are undominated.)

None of these constraints is really new; see Myers (1997) or Yip (2002), among others, for similar proposals.

In HS far more than in P-OT, the details of the candidate generator GEN are important, because GEN determines exactly how much a candidate can differ from its input. The natural assumption for autosegmental phonology is that GEN can insert or delete exactly one association line at a time. We also make the standard assumption that GEN cannot produce structures with crossing association lines.

We will illustrate this system with an HS analysis of a hypothetical language with left-to-right tone association. (This language is essentially Kikuyu without tone shift.) The underlying representation consists of segmental material for four syllables and an equal number of unassociated tones. The derivation in (18) is typical of what the analysis has to do:

(18) Derivation for left-to-right language

Underlying	Step 1	Step 2	Step 3	Step 4	Step 5 (convergence)
L H L H patakasa	L H L H | patakasa	L H L H | | patakasa	L H L H | | | patakasa	L H L H | | | | patakasa	L H L H | | | | patakasa

The candidates available at the first step of the derivation, some of which are shown in tableau (19), consist of all the ways of applying either of the operations in (1) exactly once, plus the faithful candidate. (Because the input has no associations, only the linking operation in (1) is in fact applicable.) The faithful candidate (19)b loses because the faithfulness constraint IDENT(tone) is ranked below NO-FLOAT and HAVE-TONE. The others (19)c,d lose because LINK-INITIAL favors candidate (19)a, where the first tone and first syllable are associated with one another.

(19) Step 1 of one-to-one left-to-right association

L H L H patakasa	NO-FL	HAVE-T	NO-SK(t)	NO-SK(s)	LNK-INIT	ID(t)
a. → L H L H | patakasa	3	3				1
b. L H L H patakasa	4 **W**	4 **W**			1 **W**	**L**
c. L H L H \\ patakasa	3	3			1 **W**	1
d. L H L H | patakasa	3	3			1 **W**	1

At step 2 (tableau (20)), the no-skipping constraints are important. NO-FLOAT and HAVE-TONE continue to compel tone association, and the no-skipping constraints determine that the next tone and syllable associated must be adjacent to the last tone and syllable associated. The candidates include the unchanged output of step 1, all of the ways of adding a single association line to it, and a candidate that has removed its lone association line (20)e:

(20) Step 2 of one-to-one left-to-right association

`L H L H`
`|`
`patakasa`
	NO-FL	HAVE-T	NO-SK(t)	NO-SK(s)	LNK-INIT	ID(t)

a. → `L H L H`
`| |`
`patakasa`
	2	2				1

b. `L H L H`
`|`
`patakasa`
	3 **W**	3 **W**				**L**

c. `L H L H`
`| \`
`patakasa`
	2	2		1 **W**		1

d. `L H L H`
`| /`
`patakasa`
	2	2	1 **W**			1

e. `L H L H` `patakasa`	4 **W**	4 **W**			1 **W**	1

The derivation continues like this until it converges at step 5.

The derivation in (19)–(20) involves an example with equal numbers of tones and syllables. When the number of syllables is larger than the number of tones, as in (21), then the last tone will spread to any toneless syllables because of HAVE-TONE. When the number of tones is larger, as in (22), NO-FLOAT will force creation of a contour tone, unless some higher ranking constraint prevents it.

(21) Step 4 from /patakasa, LHL/

`L H L`
`| | |`
`patakasa`
	NO-FL	HAVE-T	NO-SK(t)	NO-SK(s)	LNK-INIT	ID(t)

a. → `L H L`
`| | |\`
`patakasa`
						1

b. `L H L`
`| | |`
`patakasa`
		1 **W**				**L**

(22) Step 4 from /pataka, LHLH/

`L H L H`
`| | |`
`pataka`
	NO-FL	HAVE-T	NO-SK(t)	NO-SK(s)	LNK-INIT	ID(t)

a. → `L H L H`
`| | |/`
`pataka`
						1

b. `L H L H`
`| | |`
`pataka`
	1 **W**					**L**

Kikuyu follows this pattern in all respects except one: it requires the first tone to be linked to two syllables. Although Clements (1984: 330-331) has an interesting proposal about why this should be so, in the interest of simplicity we will opt here for an ad hoc constraint:

(23) INITIAL-PLATEAU (INIT-PLAT) (ad hoc constraint)[5]

Assign a violation mark if the initial tone is linked to fewer than two syllables.

We now have the resources we need to analyze Kikuyu. Since /tomarɔrirɛ, LHLH/ contains five syllables and four tones, there are 20 ways of adding a single association line to it at step 1. That is the candidate set. Only one of these candidates satisfies LINK-INITIAL, which is the only constraint (other than faithfulness) that distinguishes among them, as tableau (24) shows.

(24) Step 1 from /tomarɔrirɛ, LHLH/

L H L H tomarɔrirɛ	HAVE-T	NO-SK(t)	NO-SK(s)	LNK-INIT	INIT-PLAT	NO-FL	ID(t)
a. → L H L H │ tomarɔrirɛ	4				1	3	1
b. L H L H tomarɔrirɛ	5 **W**			1 **W**	1	4 **W**	**L**
c. L H L H ╲ tomarɔrirɛ	4			1 **W**	1	3	1
d. L H L H │ tomarɔrirɛ	4			1 **W**	1	3	1

At the second step, the available options include spreading the first tone (25)a, doing nothing (25)b, one-to-one linking (25)c, creation of a contour tone (25)d, and delinking (25)e. Spreading of the first tone is required by INITIAL-PLATEAU. For it to take precedence over one-to-one linking, INITIAL-PLATEAU has to dominate NO-FLOAT:

[5] The factorial typology of this constraint set on inputs like the one in (24) was computed with OT-Help (Staubs et al. 2010). The results were consistent with expectations except for a pattern where the contour tone appears on the *second* syllable. This pattern is produced under rankings where INITIAL-PLATEAU dominates IDENT(t), but the constraints giving one-to-one left-to-right association dominate INITIAL-PLATEAU. This results in a contour tone on the second syllable because satisfaction of INITIAL-PLATEAU is the last step before convergence. This prediction is implausible, and it suggests unsurprisingly that the ad hoc constraint INITIAL-PLATEAU is somewhat off the mark.

(25) Step 2 from /tomarɔrirɛ, LHLH/

L H L H | tomarɔrirɛ	Have-T	No-Sk(t)	No-Sk(s)	Lnk-Init	Init-Plat	No-Fl	Id(t)
a. → L H L H |\\ tomarɔrirɛ	3					3	1
b. L H L H | tomarɔrirɛ	4 **W**				1 **W**	3	**L**
c. L H L H | | tomarɔrirɛ	3				1 **W**	2 **L**	1
d. L H L H |/ tomarɔrirɛ	4 **W**				1 **W**	2 **L**	1
e. L H L H tomarɔrirɛ	4 **W**			1 **W**	1 **W**	4 **W**	1

Observe that delinking of the previously associated tone, as in (25)e, is harmonically bounded by the winner (25)a. This will become important when we consider the effects of lexical associations.

One-to-one left-to-right association prevails at the next step of the derivation, where it is favored by the no-skipping constraints. In this respect, the Kikuyu step-3 tableau (26) is identical with the step-2 tableau of the hypothetical example in (20).

(26) Step 3 from /tomarɔrirɛ, LHLH/

L H L H |\\ tomarɔrirɛ	Have-T	No-Sk(t)	No-Sk(s)	Lnk-Init	Init-Plat	No-Fl	Id(t)
a. → L H L H |\\ | tomarɔrirɛ	2					2	1
b. L H L H |\\ tomarɔrirɛ	3 **W**					3 **W**	**L**
c. L H L H |\\ | tomarɔrirɛ	2	1 **W**	1 **W**			2	1
d. L H L H |\\ | tomarɔrirɛ	2		1 **W**			2	1
e. L H L H |\\ | tomarɔrirɛ	2	1 **W**				2	1
f. L H L H |\\\\ | tomarɔrirɛ							

The pattern of one-to-one left-to-right association continues at step 4:

(27) Step 4 from /tomarɔrirɛ, LHLH/

L H L H tomarɔrirɛ	HAVE-T	NO-SK(t)	NO-SK(s)	LNK-INIT	INIT-PLAT	NO-FL	ID(t)
a. → L H L H tomarɔrirɛ	1					1	1
b. L H L H tomarɔrirɛ	2 **W**					2 **W**	**L**
c. L H L H tomarɔrirɛ	1		1 **W**			1	1
d. L H L H tomarɔrirɛ	1	1 **W**				1	1

At step 5, the last unlinked tone associates with the last unlinked syllable:

(28) Step 5 from /tomarɔrirɛ, LHLH/

L H L H tomarɔrirɛ	HAVE-T	NO-SK(t)	NO-SK(s)	LNK-INIT	INIT-PLAT	NO-FL	ID(t)
a. → L H L H tomarɔrirɛ							1
b. L H L H tomarɔrirɛ	1 **W**					1 **W**	**L**

Finally, at step 6, the derivation converges on the correct surface form:

(29) Step 6 from /tomarɔrirɛ, LHLH/ — Convergence

L H L H tomarɔrirɛ	HAVE-T	NO-SK(t)	NO-SK(s)	LNK-INIT	INIT-PLAT	NO-FL	ID(t)
a. → L H L H tomarɔrirɛ							
b. L H L H tomarɔrirɛ							1 **W**

The analysis just presented is strictly structure-building. The original inputs to the system have no tone-syllable associations, and the ultimate outputs have no toneless syllables and floating tones only when contours are impossible. Structure is built in a strictly monotonic fashion: although GEN as defined in (1) includes a delinking operation, at no point in this dervation was it optimal to remove an association line. Kikuyu's monotonic structure-building derivations are, moreover, monotonically harmonically improving with respect to HAVE-TONE and NO-FLOAT. Each added association line improves performance on one or more of these constraints. Removing association lines only degrades performance, making the representation less harmonic rather than more.

5. Effect of lexical tone linking

This analysis, which was worked out under the assumption that tones are unassociated in the lexicon, fails when confronted with lexical associations. To show this, we will examine the threshold case, where every tone is lexically linked, and show that the HS analysis is unable to bring it into conformity with the observed regularities of tone association in Kikuyu.

The phonology of Kikuyu should be able to map the underlying representation in (30)a to the surface representation in (30)b:

(30) Effect of lexical linking

```
     a. Underlying form          b. Desired surface form
         L H L H                    L    H LH
         | | | |                    |\   | |/
        patakasa                   patakasa
```

This requirement follows because the grammar has to capture some basic generalizations about tone in this language: the underying tones of non-initial, non-final morphemes appear one syllable to their right in the surface form; the first two syllables have a level tone; and contour tones are confined to the final syllable. Section 4 presented a grammar that captures these generalizations when the underlying form has only unlinked tones. As we will now show, the same grammar is unable to accomplish the mapping in (30), which means that it is sometimes unable to capture these generalizations when the underlying representation has linked tones.

At step 1, INITIAL-PLATEAU prevails, and the first tone spreads to the second syllable, creating a LH contour tone on it, as in (31):

(31) Step 1 from /paL taH kaL saH/

`L H L H` `|		|` `patakasa`	HAVE-T	NO-SK(t)	NO-SK(s)	LNK-INIT	INIT-PLAT	NO-FL	ID(t)
a. → `L  H L  H` `/\/		` `pa ta ka sa`							1
b. `L H L H` `|		|` `patakasa`					1 **W**		**L**
c. `L H L H` `|	|` `patakasa`	1 **W**	1 **W**	1 **W**		1 **W**	1 **W**	1

At step 2, the grammar converges on the output of Step 1:

(32) Convergence at step 2 from /paL taH kaL saH/

L H L H pa ta ka sa	HAVE-T	NO-SK(t)	NO-SK(s)	LNK-INIT	INIT-PLAT	NO-FL	ID(t)
a. → L H L H pa ta ka sa							
b. L H L H pa ta ka sa		1 **W**				1 **W**	1 **W**
c. L H L H pa ta ka sa							1 **W**

This is not a welcome result. Starting from an underlying representation where tones and tone-bearers are linked one-to-one, the grammar produces a result with a contour tone on the second syllable. This is at odds with the facts of Kikuyu, which allows contour tones only on the final syllable.

The source of this problem is evident from (32). To get from (32)a to a final result that has a contour tone on the final syllable, the H linked to the second syllable needs to shift to the third syllable, forcing the L on the third syllable to shift to the fourth and final syllable. (In longer words, obviously, more intermediate steps will be required). The only way to accomplish this within our assumptions about GEN is for one of the losers in (32) to win. But both are harmonically bounded by the winner, which means that no ranking of these constraints can make winners of them.

The harmonic bounding in (32) can be broken by introducing another constraint that favors one of the losers over the unwanted winner. One plausible option is NO-MEDIAL-CONTOUR (NO-MC) (cf. Zoll 2003), which favors (32)b over (32)a. It has to be ranked below INITIAL-PLATEAU, since creating the plateau produces a medial contour tone. But if it dominates NO-SKIP(tone) and NO-FLOAT, it can force simplification of the contour tone created at step 1 by delinking the H part of the contour:

(33) Step 2 from /paL taH kaL saH/ with NO-MEDIAL-CONTOUR

L H L H pa ta ka sa	NO-SK(s)	INIT-PLAT	LNK-INIT	HAVE-T	NO-MC	NO-SK(t)	NO-FL	ID(t)
a. → L H L H pa ta ka sa						1	1	1
b. L H L H pa ta ka sa					1 **W**	**L**	**L**	**L**

At the next step, the floating H needs to reassociate with the third syllable, but that is impossible under this ranking. The problem (see tableau (34)) is that reassociating the floating H violates NO-MEDIAL-CONTOUR, while the floating H itself violates only NO-SKIP(tone) and NO-FLOAT. As we just saw in (33), these constraints have to be ranked below NO-MEDIAL-CONTOUR to get step 2 to work right.

(34) Convergence at step 3 on output of (33)

L H L H / pa ta ka sa	NO-SK(s)	INIT-PLAT	LNK-INIT	HAVE-T	NO-MC	NO-SK(t)	NO-FL	ID(t)
a. → L H L H / pa ta ka sa						1	1	
b. L H L H / pa ta ka sa					1 **W**	**L**	**L**	1 **W**

Clearly, introducing NO-MEDIAL-CONTOUR does not in general help to map underlying representations with linked tones onto the actual surface tone pattern of Kikuyu. With or without this constraint, the HS analysis only works reliably when underlying representations are limited to unassociated tones.

Analysis in HS depends on assumptions about GEN as well as CON. In section 2, we argued for a maximally simple GEN with just two operations on autosegmental association lines, insertion or deletion of a single line. We specifically argued against including an operation that is able to reassociate, shifting a tone from one syllable to the next in a single step. As it turns out, even if GEN included such an operation, it would not help with the problem of lexically associated tones. This operation adds another relevant candidate to those listed in (33). This candidate, which is shown in (35)c, is no improvement — in fact, it is harmonically bounded by (35)b, which has no changes at all.[6]

(35) Step 2 from /paL taH kaL saH/ with flop

L H L H / pa ta ka sa	NO-SK(s)	INIT-PLAT	LNK-INIT	HAVE-T	NO-MC	NO-SK(t)	NO-FL	ID(t)
a. → L H L H / pa ta ka sa						1	1	1
b. L H L H / pa ta ka sa					1 **W**	**L**	**L**	**L**
c. L H L H / pa ta ka sa					1 **W**	**L**	**L**	2 **W**

In contrast, underlying tone associations present no difficulties for a P-OT analysis. As long as IDENT(tone) is ranked low enough, underlying representations with linked and unlinked tones map to the same outputs. Precisely because IDENT(tone) is bottom-ranked, the markedness constraints overwhelm any faithfulness effects and thereby fully determine the tonal pattern of the output, regardless of whether or how tones are linked in the input. Tableaux (36) and (37) illustrate:[7]

[6] Another imaginable approach would be to replace NO-MEDIAL CONTOUR with a gradient constraint ALIGN-R(contour tone, word). This constraint would break the harmonic bounding in (35) by favoring (35)c over (35)b, because (35)c's contour tone is one syllable further to the right than (35)b's. The problem with this constraint is that it makes implausible typological predictions in other grammars. For example, it predicts the existence of a language where the penult can have a contour tone only if the ultima does, where the antepenult can have a contour tone only if the penult and ultima do, and so on. In general, licensing constraints like NO-MEDIAL CONTOUR never seem to be evaluated gradiently (Zoll 1996: 141).

[7] The ranking in (36) and (37) is based on examples like (11), which show that INITIAL-PLATEAU has to dominate NO-FLOAT.

(36) Kikuyu in parallel OT: Underlying linked tones

<table>
<tr><th>L H L H
| | | |
patakasa</th><th>NO-SK(s)</th><th>INIT-PLAT</th><th>LNK-INIT</th><th>HAVE-T</th><th>NO-MC</th><th>NO-SK(t)</th><th>NO-FL</th><th>ID(t)</th></tr>
<tr><td>a. → L H L H
|\ \ \|
patakasa</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>5</td></tr>
<tr><td>b. L H L H
| | | |
patakasa</td><td></td><td>1 W</td><td></td><td></td><td></td><td></td><td></td><td>L</td></tr>
<tr><td>c. L H L H
|\| | |
patakasa</td><td></td><td></td><td></td><td></td><td>1 W</td><td></td><td></td><td>1 L</td></tr>
<tr><td>d. L H L H
|\ | |
patakasa</td><td></td><td></td><td></td><td></td><td></td><td>1 W</td><td>1 W</td><td>2 L</td></tr>
</table>

(37) Kikuyu in parallel OT: Underlying unlinked tones

<table>
<tr><th>L H L H

patakasa</th><th>NO-SK(s)</th><th>INIT-PLAT</th><th>LNK-INIT</th><th>HAVE-T</th><th>NO-MC</th><th>NO-SK(t)</th><th>NO-FL</th><th>ID(t)</th></tr>
<tr><td>a. → L H L H
|\ \ \|
patakasa</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>5</td></tr>
<tr><td>b. L H L H

patakasa</td><td></td><td>1 W</td><td></td><td>4 W</td><td></td><td></td><td>4 W</td><td>L</td></tr>
<tr><td>c. L H L H
| | | |
patakasa</td><td></td><td>1 W</td><td></td><td></td><td></td><td></td><td></td><td>4 L</td></tr>
<tr><td>d. L H L H
|\| | |
patakasa</td><td></td><td></td><td></td><td></td><td>1 W</td><td></td><td></td><td>5</td></tr>
<tr><td>e, L H L H
|\ | |
patakasa</td><td></td><td></td><td></td><td></td><td></td><td>1 W</td><td>1 W</td><td>4 L</td></tr>
</table>

Why do P-OT and HS analyses differ so sharply in their ability to accommodate underlying representations with linked tones? Why is it that one is able to accomplish the mapping in (38) (repeated from (30)), while the other is not? Because the relationship between an underlying form and its surface form is different in P-OT and HS. In P-OT, a surface form is the most harmonic candidate derived from its underlying form. In HS, a surface form is the most harmonic candidate derived from the form that preceded it in the derivation, which is the most harmonic candidate derived from its predecessor, and so on, all the way back to the underlying form. Whether a particular surface form is accessible from some underlying form in HS depends on whether there is a series of intermediate optima linking them by a succession of small changes — in tone association, those small changes have to be drawn from (1). The mapping in (38) is impossible for the HS analysis because there is no such series of optima, as we saw when we attempted to construct one in (31)–(35).

(38) Effect of lexical linking

```
     a. Underlying form          b. Desired surface form
          L H L H                     L   H LH
          | | | |                     |\  | |/
         patakasa                    patakasa
```

There is clearly a problem for HS here. One obvious solution to this problem is to prohibit linked tones in the Kikuyu lexicon. This is in fact the solution we adopt, but it cannot be true of the lexicon of Kikuyu alone — it must be true of every language or none at all. A fundamental premise of OT is that languages differ in constraint ranking. The null hypothesis is that languages differ *only* in constraint ranking. Lexica are language-particular, of course, but all systematic differences between languages are expressed by the grammar. This thesis is called richness of the base (ROTB), because it holds that the base (= original input to the grammar) is rich in the sense that it is not subject to any language-particular restrictions. ROTB does not rule out language-universal restrictions on inputs, however. For instance, the PARSE/FILL theory of faithfulness in Prince & Smolensky (1993/2004) relied on the assumption that inputs contain no syllable structure.

ROTB rules out a fairly standard pre-OT analytic move of saying that tones are underlyingly unlinked in languages where tone association is fully predictable, such as Kikuyu, but they are underlyingly linked in languages where tone association is unpredictable, such as Japanese. If we are to say that tones are underlyingly unlinked in the lexicon of Kikuyu, as the argument just presented shows, then we are obliged under ROTB to say that they are underlyingly unlinked in *all* languages.

Although our reasons for taking this position are novel, the position itself is not. According to Odden (1995: 468), "The view that tones and segments are underlyingly separated was pursued in early autosegmental phonology to the point that in Goldsmith (1976a) there are no lexical linkings between tones and vowels." Lexical tone association was seen as unnecessary, and hence excluded by Occam's Razor. The assumptions that made it unnecessary in Goldsmith (1976a) are also relevant to our proposal, as the next section will show.

6. Lexical tone association: Evidence and response

Tone association is not always entirely predictable from simple phonological principles like those operative in Kikuyu. In such cases, a surface contrast in tone association has to be encoded in the lexicon. We have argued that direct encoding is not an option. What alternatives are available?[8]

There is a tradition of work on tone in Bantu and Japanese that posits diacritic accent (Goldsmith 1976a, 1982, 1984b, Haraguchi 1977, Hyman 1981, 1982, Hyman & Byarushengo 1980, Odden 1982, 1985). A diacritic accent is a phonetically uninterpretable lexical feature of a vowel that attracts a particular tone, H or L. In the literature on Bantu, the primary purpose of

[8] Besides the two mentioned in the text, there is a third possible source of surface tone-association contrasts. When contrasts emerge because different parts of the lexicon are subject to different regularities, lexical indexation of ranking and/or constraints may be the best analysis (Inkelas 1999: 143, Pater 2000, 2006, and others).

the diacritic accent is to allow for a modular system in which the locations of tones can be manipulated by rules prior to insertion of tone melodies (Goldsmith 1982: 48). In the literature on Japanese, however, diacritic accent is primarily used to mark contrasts in tone association. This idea is revisited and situated in HS in McCarthy & Pruitt (to appear), so we will not develop it further here.

Instead, we will focus here on a purely tonal source for tone-association contrasts. In the early autosegmental literature, apparent contrasts in tone association were sometimes attributed to contrasts in the tone melody itself. In Etung (Niger-Congo, Nigeria), for example, there are contrasting tone patterns like *ákpùgà* 'money' versus *ésébè* 'sand'.[9] If these words are assumed to have the same HL tone melody, then underlying tone association would seem unavoidable. In Goldsmith's (1976a: 221ff.) analysis of Etung, however, these words are analyzed with different melodies: HL in *ákpùgà* and HHL in *ésébè*. If these are the underlying representations, then tone association can be fully determined by the grammar. Venda exemplifies this kind of analysis.

Venda has been cited as a Bantu language with an unusually wide range of contrasting tone patterns (Kisseberth & Odden 2003: 59). It has also provided the basis for an explicit argument in support of underlying tone association (Cassimjee 1992: 77--80). It therefore merits our close attention as representative of the kinds of challenges a theory without underlying tone association must face.

Here, we reanalyze the Venda evidence in HS under ROTB. As we showed in the analysis of Kikuyu, ROTB only forces HS to ban underlying tone associations. ROTB also rules out a key assumption that made underlying tone association necessary in the first place: the assumption that underlying representations are subject to the Obligatory Contour Principle (OCP), which prohibits adjacent identical tones (Goldsmith 1976a, Leben 1973). We argue instead that, although the OCP controls aspects of surface form, like any other markedness constraint it does not and cannot control underlying forms. Once this argument is in place, the need for underlying tone association in Venda disappears.

Venda has two tones, H and L. In noun stems, every combination of H and L is possible (Cassimjee 1992). Thus, monosyllabic nouns are H or L, disyllabic nouns are HH, LL, HL, or LH, and so on. There is complete attestation of the eight possible patterns in trisyllables, and nearly complete attestation of the 16 possible patterns in quadrisyllabic stems.

Cassimjee (1992: 77--80) uses this system of contrasts to argue for underlying tonal association. Her argument starts with a claim about the representation of high tone in Venda: tautomorphemic sequences of H autosegments are prohibited. The evidence for this claim comes from the process known as "Meeussen's Rule" (Goldsmith 1984a and much subsequent work). Meeussen's Rule is a dissimilatory process that changes the second of two adjacent H tones into L. When a stem containing several high-toned syllables in a row undergoes Meeussen's Rule, all of the high-toned syllables become low:

(39) Effect of Meeussen's Rule (gloss: 'spy')

```
H     H    H     L
|    / \   |    / \
V # ṯholi → V # ṯholi
```

From this observation, Cassimjee infers that sequences of H autosegments are prohibited in underlying representation. If such sequences were allowed in the input to Meeussen's Rule, then only the first H in the sequence would lower:

[9] High tone is indicated by an acute accent and low by a grave accent.

(40) Not the effect of Meeussen's Rule

```
H      H H  *H     L H
|      | |   |     | |
V # ṯholi → V # ṯholi
```

Cassimjee goes on to consider whether this result entails lexical tonal association under two different assumptions about L tone, underspecification and full specification. Since Venda presents no good evidence for underspecification of L, we focus on the stronger argument for lexical associations that is based on full specification.

The possible contrasts in quadrisyllables are relevant to this issue. Specifically, in her analysis HLH melodies can contrast in the choice of which H is multiply linked in quadrisyllables:[10]

(41) Contrast in H linking (with L specification)

Near-surface form	Underlying form	
	No lexical association	Lexical association
H L H /\ | | gokoshomba 'Cape grape'	H L H gokoshomba	H L H /\ | | gokoshomba
H L H | | /\ sudzungwane 'shrub species'	H L H sudzungwane	H L H | | /\ sudzungwane

Since HLH can be associated with a stem in at least two distinct, contrasting ways, lexically specified tone association would appear to be indispensible.

This argument rests on the assumption that the lexical representations of morphemes do not contain sequences of H autosegments. In other words, OCP(H) is a morpheme-structure constraint of Venda (Cassimjee 1992: 122). But OCP(H) is also active dynamically, in the course of phonological derivations. In Cassimjee's analysis, it is responsible for fusion of adjacent Hs between some prefixes and the stem in verbs (Cassimjee 1992: 124, 324). Furthermore, Meeussen's Rule has also been attributed to OCP(H), because it eliminates sequences of adjacent H tones dissimilatorily (Myers 1987, 1997 and others). When a phonological constraint has these dual roles — as a passive restriction on underlying morphemes and as an active participant in derivations — we have what is known as the Duplication Problem (Clayton 1976, Kenstowicz & Kisseberth 1977). The Duplication Problem is a problem because the analysis misses a generalization: two different grammatical components have the same constraint, with only its functions differing.

ROTB is OT's solution to the Duplication Problem (see McCarthy 2002: 71--76 for an explanation). By denying the existence of language-particular constraints on the lexicon, ROTB eliminates the possibility of this duplication. In the present instance, ROTB entails the possibility of lexical items with underlying tone sequences like HHLH and HLHH. Indeed, those can be exactly the tones of the lexical items in (41). In other words, a putative contrast in tonal association is reanalyzed as a contrast in tones themselves. Lexical association of tones is not necessary.

[10] The ultimate surface forms are *gókóshômbá* and *súdzúngw!áné*, as a result of a process that spreads the first H rightward, creating a contour tone on the (long) penult or a floating L otherwise.

The principal challenge to this analysis is the Meeussen's Rule evidence in (39). If [gókóshòmbá] has separate H tones on its first two syllables, why does Meeussen's Rule lower both of them? The answer is that there are two H tones in the lexicon, but there is only one H by the time Meeussen's Rule comes into effect because sequences of H tones on adjacent syllables have already fused to satisfy OCP(H), defined as follows:

(42) OCP(H) (after Myers 1987: 154)

Assign one violation mark for every pair of H autosegments that are adjacent on their tier and linked to adjacent syllables.

Although it compels fusion later on, OCP(H) does not affect one-to-one left-to-right association at the initial stages of the derivation. That is because it is ranked below all of the constraints that are responsible for that pattern of association, as shown in tableau (43):[11]

(43) Step 2 from /gokoshomba, HHLH/

H H L H | gokoshomba	LNK-INIT	NO-FL	HAVE-T	NO-SK(t)	NO-SK(s)	ID(t)	OCP(H)
a. → H H L H | | gokoshomba		2	2			1	1
b. H H L H | gokoshomba		3 **W**	3 **W**			**L**	**L**
c. H H L H /\\ gokoshomba		3 **W**	2			1	**L**
d. H H L H | | gokoshomba		2	2		1 **W**	1	**L**
e. H H L H | / gokoshomba		2	2	1 **W**		1	**L**

This derivation continues in the same vein, eventually producing [gókóshòmbá], with one-to-one association between tones and syllables:

(44) /gokoshomba, HHLH/ after step 4

```
 H H  L  H
 | |  |  |
gokoshomba
```

Now that all of the constraints ranked higher than OCP(H) have been satisfied, attention turns to it. The OCP evokes various responses in the world's languages, and among them is fusion of the offending elements (Boersma 1998, Keer 1999, Myers 1987, 1997, Yip 1988). Fusion or coalescence of identical elements violates no faithfulness constraints except UNIFORMITY (McCarthy & Prince 1995: 371). We propose that OCP(H) dominates UNIFORMITY in Venda,

[11] Also see Reynolds (1997) for a parallel OT analysis of Venda nouns in a headed domains theory of tone representation.

so (44) is transformed into a representation where a single H autosegment is associated with the first two syllables:

(45) Step 5 from /gokoshomba, HHLH/

H H L H │ │ │ │ gokoshomba	LNK-INIT	NO-FL	HAVE-T	NO-SK(t)	NO-SK(s)	ID(t)	OCP(H)	UNIF
a. → H L H /\ │ │ gokoshomba								1
b. H H L H │ │ │ │ gokoshomba							1 **W**	**L**

Fusion of identical elements does not violate IDENT (Keer 1999).

All stem-internal sequences of H autosegments will fuse in this fashion. For example, the underlying representation of *bólóngóndó* is /bolongondo, HHHH/ with three OCP(H) violations at step 4 of its derivation. These violations are removed in three steps, each of which effects fusion of one pair of adjacent Hs. The order in which these tones fuse is indeterminate, but the final result is a single H linked to four syllables.

Meeussen's Rule — that is, dissimilation of H to L — competes with fusion as a way of satisfying OCP(H). In nouns, there is a clear division of responsibility, with fusion intramorphemically and dissimilation intermorphemically.[12] The key to the analysis is that fusion is preferred to dissimilation because IDENT(H) dominates UNFORMITY(H). But hetermorphemic fusion is blocked by the constraint MORPHDIS (abbreviated MDIS), which prohibits morphemes from sharing segments, tones, or other phonological elements (Keer 1999: 53, McCarthy & Prince 1995: 310). Tableau (46) illustrates with a schematic example of a heteromorphemic sequence of high tones. Dissimilation in (46)a competes against fusion in (46)c. Since this H sequence arises across word boundary, merger is blocked by MORPHDIS and dissimilation prevails.[13]

[12] The situation in verbs is less clear; the choice between fusion and Meeussen's Rule in verbs is perhaps the most important incompletely resolved question in Cassimjee (1992).

[13] Since it is not really relevant to our concerns, we set aside the question of why Meeussen's Rule affects the second H rather than the first. See Myers (1997: 887) for one proposal.

(46) Meeussen's Rule
At step 3 from /SS,HL/ after H-final word

H # H L │ │ │ S # S S	LNK-INIT	NO-FL	HAVE-T	NO-SK(t)	NO-SK(s)	MDIS	OCP(H)	NO-LNK(t)	ID(H)	UNIF(H)
a. → H # L L │ │ │ S # S S									1	
b. H # H L │ │ │ S # S S							1 W		L	
c. H L /\ │ S # S S						1 W			L	1 W

A final detail. Some sort of cyclic analysis is required to account for cases like (39) where a H-final word is followed by a noun whose underlying representation begins in an H sequence. The stem-internal H sequence is merged on the first or lexical cycle, and then it dissimilates when the preceding H becomes visible on the second or postlexical cycle:

(47) Cyclicity in H#HH…

```
  H H           H          H      L
  | |     →    /\     →    |     /\
 ṯholi        ṯholi        V # ṯholi
```

See Wolf (2008) for a demonstration of how the cycle can be incorporated into a serial version of OT similar to HS.

As we saw in the last section, ROTB forces the conclusion that tone associations are universally absent from the lexicon. This conclusion is challenged by the complex tonal patterns of nouns in Venda, which seem to require lexical associations. But ROTB forces the analysis to include tone melodies that eliminate the need for lexical associations. In short, ROTB not only creates the problem but also solves it.

7. Conclusion

Any interesting linguistic theory has unanticipated consequences. Harmonic Serialism is interesting because it has led to a body of interesting results, such as the one described in section 2 and others cited in McCarthy (2010). Among its unanticipated consequences is its incompatibility with lexical tone linking in languages like Kikuyu where tone association is completely predictable.

As we noted in the introduction, the results in this paper converge with the conclusions about lexical marking of metrical feet in Harmonic Serialism in McCarthy & Pruitt (to appear). This convergence is no accident. In both cases, we are dealing with phonological distinctions that are represented structurally. Furthermore, in both cases there are languages where the properties of that structure are fully predictable, though there are also others where they are not. Most importantly, in both cases there are constraints favoring full parsing of the structure: with metrical feet, the primary full-parsing constraint is PARSE-SYLLABLE, and with tone the constraints are HAVE-TONE and NO-FLOAT. Lexical structure is a kind of pre-existing parse, and removing it degrades performance on these constraints. In Harmonic Serialism, under the assumption that the removal of unwanted structure and the introduction of new structure cannot occur simultaneously, lexical structure is (undesirably) invulnerable precisely because of these pro-parsing constraints.

Dealing with this consequence of Harmonic Serialism led us to explore alternative ways of lexically encoding unpredictable tone association, and this brought us back to ideas that were prevalent in earlier work on tone, particularly lexical violation of the OCP. Under richness of the base, the OCP cannot be a restriction on underlying representations, but once underlying "violations" of the OCP are admitted, an important argument for underlying tone association goes away. Our results, then, emerge from a nexus of Harmonic Serialism, the maximally simple theory of GEN in (1), and the familiar OT principle of richness of the base.

Optimality Theory has, since its outset, focused its attention on constraints on phonological substance. In his research, Norval Smith has long emphasized the importance of phonological representations. Work in Harmonic Serialism, including this chapter, shows that representational matters continue to be important. HS's theory of GEN is, to a great extent, a theory of representations and the operations on them. We therefore are seeing a convergence of two well-established and productive research programs.

Personal Remark by John McCarthy

Norval's bad luck is the reason why I am a contributor to this *Festschrift*. I was invited because I am listed as his co-author on an article in the *Oxford Encyclopedia of Linguistics* (2nd edition). That co-authorship came about through a complicated set of circumstances. In 2001, I was in charge of the phonology articles in the encyclopedia, and Norval was supposed to be revising his article from the first edition. He could not because he was undergoing treatment for cancer, and so I took care of the revisions. As we all know, Norval got well, the encyclopedia was published, and a decade later I have the privilege of honoring someone I have always admired for his broad interests and openness to new ideas.

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