Irreducible parallelism in phonology: evidence for lookahead in Mohawk, Maragoli, Lithuanian, Sino-Japanese, and beyond

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Abstract

McCarthy (2013) asks whether there truly are phonological systems necessitating irreducible parallelism in grammar. That is, are there systems that require that multiple changes to the input apply in a single derivational step? Such a system would necessitate a grammatical framework with lookahead: the ability to see from a given derivational step the results of subsequent steps. The constraint-based framework Parallel Optimality Theory (OT) has full lookahead, while its serial counterpart, Harmonic Serialism (HS), has no lookahead. This paper makes the following claims: (i) a variety of systems across languages, involving a diverse array of processes, require lookahead; (ii) these systems share the same abstract structure, despite superficial differences. Our evidence comes primarily from the distribution of stress, lengthening, and epenthesis in Mohawk; reduplication and hiatus repair in Maragoli; assimilation and epenthesis in Lithuanian; and syncope and gemination in Sino-Japanese. All these systems involve what we call a COMPARISON OF PROCEDURES. To best satisfy constraints, the grammar applies one change followed by another, unless the final result is dispreferred. In such a case, the grammar instead applies a different series of changes. We prove at an abstract level that HS, due to its gradualness requirement, is unable to express a comparison of procedures unless the changes involved take place in a single step. In this way, the changes involved are irreducibly parallel. HS fails in the same way for all our cases, whereas Parallel OT succeeds.

Keywords: Parallelism, Optimality Theory, Harmonic Serialism, Mohawk, Maragoli

1. Introduction

In Parallel Optimality Theory (henceforth Parallel OT; Prince and Smolensky 1993/2004), GEN can generate output candidates that differ from the input by an unbounded number of changes (assign stress, spread feature, etc.; also called operation; McCarthy 2010a, 2010b). All candidates are compared in a single input-output mapping. In the serial instantiation of Optimality Theory, Harmonic Serialism (henceforth HS; McCarthy 2010a, McCarthy and Pater 2016, and references therein), GEN can only generate candidates in which the output differs from the input by at most one change. Constraint satisfaction is gradual: each successive input in a series of linearly-ordered input-output mappings, or steps, differs from the previous by maximally one harmonically improving change. Within each step, the decision as to which candidate is optimal is made solely based on the candidates present in that step. That is, the grammar has no lookahead: no information

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about what sorts of candidates could become available at any future step in the derivation. Thus, `EVAL` chooses the most immediately optimal candidate. In Parallel OT, on the other hand, because all candidates are compared simultaneously, entire derivational paths can be compared. While HS has no lookahead, Parallel OT has full lookahead.

To illustrate what we mean by lookahead, imagine that an input /x/ undergoes one of two series of distinct changes, shown in (1).

(1)  
**UR: /x/**  
**A Series:**  
\[ x \rightarrow A_1(x) \rightarrow A_2(A_1(x)) \]  
**B Series:**  
\[ x \rightarrow B_1(x) \]

In Parallel OT, \( A_2(A_1(x)) \) can be compared against \( B_1(x) \), but in HS, it cannot: \( A_2(A_1(x)) \) only becomes present in the derivation if \( A_1(x) \) wins in Step 1. As a result, given certain violation profiles, different candidates will be predicted to win.

(2) displays a Parallel OT tableau of the candidates `GEN` generates given (1), with hypothetical violation profiles of two ranked constraints. The winner is the candidate that represents the full application of the A series, \( A_2(A_1(x)) \).

<table>
<thead>
<tr>
<th></th>
<th>/x/</th>
<th>C₁</th>
<th>C₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>𝑃_1(x)</td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>𝑃_2(𝑃_1(x))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td>𝑃_3(x)</td>
<td>*!</td>
<td></td>
</tr>
</tbody>
</table>

Compare (2) with the HS tableaux in (3-4). `GEN` cannot generate \( A_2(A_1(x)) \) at Step 1 (indicated by gray shading). Hence, `EVAL` only chooses between \( A_1(x) \) and \( B_1(x) \). Given the violation profiles, \( B_1(x) \) wins. In the next step, given the input \( B_1(x) \), `GEN` cannot generate \( A_2(A_1(x)) \). \( A_2(A_1(x)) \) never enters the candidate set of any step, and the derivation converges on \( B_1(x) \). Thus, \( A_2(A_1(x)) \) wins in Parallel OT, but \( B_1(x) \) wins in HS. In HS, the derivation cannot lookahead to know that \( A_2(A_1(x)) \) is the overall most harmonic form.

<table>
<thead>
<tr>
<th></th>
<th>/x/</th>
<th>C₁</th>
<th>C₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>1</td>
<td>𝑃_1(𝑃_1(x))</td>
<td>*!</td>
</tr>
<tr>
<td>b.</td>
<td>2</td>
<td>𝑃_2(𝑃_1(𝑃_1(x)))</td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td>1</td>
<td>𝑃_3(𝑃_1(x))</td>
<td>*</td>
</tr>
</tbody>
</table>

Given candidates with the same violation profiles, Parallel OT and HS make distinct predictions. Which predictions are correct is an empirical question. Prince & Smolensky (1993/2004) and McCarthy & Prince (1995) have argued that top-down interactions and reduplication-repair phenomena necessitate parallel derivation. Recently, however, McCarthy, Pater & Pruitt (2016)
and McCarthy, Kimper & Mullin (2012), respectively, show that HS can express top-down interactions and reduplication-repair phenomena. Walker (2010) argued for parallel derivation based on a set of metaphony patterns, but Kimper (2012) shows that HS can derive them too using constraints independently needed to capture typological generalizations about harmony. Hence, whether parallel or serial models of grammar better match the data remains an open question. Beyond choice of grammatical architecture, the answer to whether the grammar has lookahead would have implications for theories of how speakers acquire phonological patterns (Smolensky 1996, Prince & Tesar 2004, Tessier & Jesney 2014) and how computationally complex these patterns can be (Heinz 2011, Heinz & Lai 2013, Bjorkman & Dunbar 2016, Jardine 2016, Heinz to appear; cf. Johnson 1972, Kaplan & Kay 1994).

This paper argues that lookahead is part of the phonological grammar. We demonstrate that a variety of systems across languages, involving a diverse array of processes, require lookahead. Furthermore, we demonstrate that these systems share the same abstract structure, despite superficial differences.

Mohawk stress exemplifies this abstract structure. In Mohawk, all words have a strictly bimoraic foot (Rawlins 2006 and Adler 2016; data from Michelson 1988, 1989). Bimoraic footing is guaranteed through one of two sets of changes, or PROCEDURES, depending on the environment. If the vowel occupying an open penult is underlying, a monosyllabic foot is built, and the tonic vowel is lengthened (5a). But if the vowel occupying an open penult is epenthetic, monosyllabic footing and lengthening would result in a marked long epenthetic vowel. Hence, a disyllabic trochee is built instead (5b). To correctly predict when monosyllabic footing and lengthening should apply versus disyllabic footing, the grammar must be able to look ahead to the result of monosyllabic footing and lengthening to determine whether a long epenthetic vowel would be formed.

(5)  
(5a) **Procedure A:** Build monosyllabic foot... then lengthen tonic vowel.  
/k-haratat-s/ → kha(ˈra)tats kha(ˈra)tats → [kha(ˈra):tats]

(5b) **Procedure B:** Build disyllabic foot instead  
/te-k-rik-s/ → [(ˈte.ke)riks]; *[te(ˈkeː)riks]

This is an instance of what we call a COMPARISON OF PROCEDURES. To best satisfy constraints, the grammar applies one change followed by another, unless the full result is dispreferred. In such a case, the grammar instead applies a different series of changes. We prove at an abstract level that HS, due to its gradualness requirement, is generally unable to compare entire procedures. The changes involved must apply in a single derivational step – they are irreducibly parallel. We argue that a variety of attested systems involving a diverse array of processes are instances of comparisons of procedures, and thus, require lookahead. To be clear, HS could express any single case by specifying that changes involved in that case are free to apply together with other changes (cf. McCarthy 2010b on syllabification applying freely with at least deletion). However, in order to express the variety of cases covered here – which involve footing, epenthesis, copying, different kinds of hiatus repairs and assimilations, and more – we would have to designate that a diverse array of changes apply together with other changes. This suggests that derivational lookahead is not merely a property associated with a restricted subset of changes (McCarthy 2010b), but rather with the grammar as a whole.

This paper is organized as follows. In Section 2, we argue that a descriptively and explanatorily adequate analysis of the distribution between footing, lengthening, and epenthesis in
Mohawk involves comparing whole procedures. Accordingly, Parallel OT captures the data, while HS does not. In Section 3, we provide a precise, abstract definition of a comparison of procedures, and prove that HS cannot express such a comparison unless the changes involved are irreducibly parallel. The rest of the paper shows that a variety of systems across languages, involving a diverse array of processes, require comparing whole procedures. Section 4 gives an in-depth investigation into a reduplication-repair interaction in Maragoli, while Section 5 covers assimilation and epenthesis in Lithuanian, syncope and gemination in Sino-Japanese, and other cases. HS fails in the same way in the face of each of our cases due to its gradualness requirement, whereas Parallel OT accounts for them naturally. Section 6 concludes.

2. A comparison of procedures in Mohawk

We introduce comparisons of procedures with the case of Mohawk stress. We show that to correctly account for the distribution of footing, vowel lengthening, and epenthesis in Mohawk, the grammar has to be able to look ahead to the final result of applying footing and lengthening. In this way, footing and lengthening are argued to be irreducibly parallel.

2.1 The data

We first introduce the basic Mohawk stress system, followed by [g]-epenthesis. When the vowel occupying the penultimate syllable is underlying, the penultimate syllable is always stressed. If the penult is closed, it receives stress, and no other (stress-related) processes occur (6). If the penult is open, it receives stress, and the tonic vowel is lengthened (7). The basic Mohawk stress pattern, then, is one of simple penult stress.

(6) Closed penult, underlying penult vowel: penult stress
   a. /k-atirut-haʔ/ [ka.ti.ˈrut.haʔ] 1A-pull-HAB 53
   b. /k-ohar-haʔ/ [ko.ˈhar.haʔ] 1A-attach-HAB 53
   c. /te-wak-teny-u/ [te.wak.ˈten.yu] DU-1P-change-STAT 122

(7) Open penult, underlying penult vowel: penult stress, tonic vowel lengthening
   a. /k-haratat-s/ [kha.ˈraː.tat.s] 1A-lift-HAB 53
   b. /wak-aruʔatat-u/ [wa.kə.ruʔ.ˈtaː.tu] 1P-blow-STAT 59
   c. /k-hyatsu-s/ [ˈkʰyaː.tuʃ] 1A-write-HAB 53
   e. /ka-huweyΛ-Ø/ [ka.hu.ˈweː.yΛ] NA-boat-NSF 142

Furthermore, [g] is inserted between the first two members of sequences of three consonants (8), and between oral consonant-sonorant sequences (9).\footnote{All data come from Michelson (1988, 1989). For analyses of Mohawk stress see Michelson (1988, 1989), Potter (1994), Ikawa (1995), Piggott (1995), Hagstrom (1997), Rowicka (1998), Alderete (1999), Rawlins (2006), Houghton (2013), and Elfner (2016). We use the (1988) transcription system, but follow Michelson (1989), Rawlins (2006), and Elfner (2016) in leaving out allophonic processes like /h/ insertion before /th/ clusters. [a] and [u] are front and back nasal vowels, respectively, [y] a palatal glide, and [ts] an affricate. All data are marked with page numbers. Those marked with an asterisk come from Michelson (1989); otherwise, Michelson (1988).} Like Rawlins (2006), Houghton (2013), and...
Elfner (2016), we analyze epenthesis in these environments, respectively, as avoidance of complex consonants clusters violating the Sonority Sequencing Principle (Steriade 1982, Selkirk 1984, Clements 1990, a.o.), and avoidance of heterosyllabic clusters with rising sonority (i.e., bad syllable contact; Murray and Vennemann 1983, Davis and Shin 1999, Rose 2000, Gouskova 2004). Note that [e] does not break up [Cy] and [kw] sequences, despite seemingly resulting in bad syllable contact when syllabified apart (Michelson 1988; see forms in 8c and forms in 9a). An analysis of the specifics of Mohawk phonotactics lies outside the scope of this paper.

(8) **Complex consonant cluster avoidance**

a. /s-k-ahkt-s/  [ˈskah.kgts] ITER-1A-go.back-HAB 135  
b. /wak-nyak-s/  [wa.ˈkgn.yaks] 1P-get.married-HAB 135  
c. /te-k-ahsutr-haʔ/  [te.kah.su.ˈtegr.haʔ] DU-1A-splice-HAB 142

(9) **Bad syllable contact avoidance**

a. /wak-ruhyaŋa-ʔ/ [wa.kg.ru.ˈyaː.kx] 1P-suffer-STAT 134  
b. /te-k-raʔnekar-us/  [te.kg.raʔ.ne.ˈkaː.rus] DU-1A-burst, pop-HAB *41  
c. /t-ni-nuhweʔ-s/  [tɛ.ni.ˈnuːweʔs] lin-d-like-HAB 134

Epenthesis interacts with stress when [e] is inserted into the penult. If [e] occupies a closed penult, the penult simply gets stressed (10). If [e] occupies an open penult, though, the antepenult gets stressed (11). And, even if the antepenult is open, the tonic vowel stays short.

(10) **Closed penult, epenthetic penult vowel: penult stress**

a. /wak-nyak-s/  [wa.ˈkgn.yaks] 1P-get married-HAB 134  
b. /te-k-ahsutr-haʔ/  [te.kah.su.ˈtegr.haʔ] DU-1A-splice-HAB 142  
c. /k-rh-o-s/  [ˈkɛr.hos] 1A-coat, spread-HAB 137  
d. /ak-tshe-ʔ/  [aˈktʃeʔ] 1P-container.jar-NSF *42

(11) **Open penult, epenthetic penult vowel: antepenult stress, no vowel lengthening**

a. /te-k-rik-s/  [ˈte.kɛ.riks] DU-1A-put together-HAB 133  
b. /t-a-k-r-ʔ/ [ˈta.kg.ɾaʔ] FUT-1A-put in-PUNC 134  
c. /w-akra-s/  [ˈwa.kg.ras] NA-smell-HAB 141  
d. /te-a-k-ahsutr-ʔ/ [ˈta.kah.ˈsu.te.ɾaʔ] DU-FUT-1A-splice-HAB 142

Note that the evidence for morpheme-internal epenthesis in (11c-d) is that such forms pattern like forms with epenthesis at morpheme boundaries (e.g. 11a-b) with respect to stress (Michelson 1988, 1989). (12) provides an example of [e] alternating for lengthening, not stress, in closed versus open syllables. This is typical of underlying vowels. In (13), though, [e] alternates with stress, not lengthening, which is typical of epenthesis. And, the contrast cannot be due to differences in the quality of the penult vowel in (12) versus (13), because the phonetic realization of epenthetic [e] is identical to the realization of underlying [e] (Michelson 1988, pg. 132).

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5 Note that vowels are deleted in hiatus contexts (Michelson 1988, 1989)
2.2 Mohawk comparison of foot building procedures

In summary, closed penults in Mohawk always receive stress, whether the penult vowel is underlying (14a) or epenthetic (14b). In open penults, if the penult vowel is underlying, the penult is stressed, and the tonic vowel is lengthened (14c). If the penult vowel is epenthetic, the antepenult is stressed, and no tonic vowel lengthening occurs (14d). Rawlins (2006) provides an elegant analysis of these facts in terms of the choice between two types of a moraic trochee, (′H) and (′LL) (Mester 1994, Hayes 1995, McCarthy & Prince 1996).

<table>
<thead>
<tr>
<th>(14)</th>
<th>Closed Penult</th>
<th>Open Penult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underlying</td>
<td>a. /k-atirut-haʔ/ [ka.ti.ˈrʌt.haʔ]</td>
<td>c. /k-haratat-s/ [ka.ˈraː.tats]</td>
</tr>
<tr>
<td></td>
<td>b. /wak-nyak-s/ [wə.ˈkɛn.yaks]</td>
<td>d. /te-k-rik-s/ [ˈte.kɛ.riks]</td>
</tr>
</tbody>
</table>

Informally, Rawlins’ Parallel OT analysis is as follows: a constraint demanding strictly bimoraic feet is undominated. Normally, this constraint is satisfied by a penult (′H) — coda consonants (15a-b) and vowel lengthening (15c) supply the second mora. But, when a constraint against long epenthetic vowels disfavors (′H) (e.g. *[te(ˈkɛː)riks]), an (′LL) trochee emerges (15d).6

<table>
<thead>
<tr>
<th>(15)</th>
<th>Closed Penult</th>
<th>Open Penult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underlying</td>
<td>a. /CV(C)CV/ [CV(ˈCVC)CV]</td>
<td>c. /CV(C)CV/ [CV(ˈCV:CV)]</td>
</tr>
<tr>
<td></td>
<td>/k-atirut-haʔ/ [ka.ti.ˈrʌt.haʔ]</td>
<td>/k-haratat-s/ [ka.ˈraː.tats]</td>
</tr>
<tr>
<td>Epenthetic</td>
<td>b. /CVCCCV/ [CV(ˈCɛC)CV]</td>
<td>d. /CVCrV/ [ˈCV.Cɛ̃rV]</td>
</tr>
<tr>
<td></td>
<td>/wak-nyak-s/ [wə.ˈkɛn.yaks]</td>
<td>/te-k-rik-s/ [ˈte.kɛ.riks]</td>
</tr>
</tbody>
</table>

The choice between monosyllabic footing and lengthening and disyllabic footing in open penult forms (15c vs. 15d) involves what we call a COMPARISON OF PROCEDURES (formally defined in Section 3), or a comparison between whole sequences of changes. To assess the optimal form, the grammar compares the final result of applying monosyllabic footing with lengthening to the result of applying disyllabic footing (16). Procedure A consists of monosyllabic footing and vowel lengthening (/k-haratat-s/ → [ka.ˈraː.tats]), while Procedure B consists of disyllabic footing (/te-k-rik-s/ → [ˈte.kɛːriks]). Though either procedure suffices to ensure a bimoraic foot, they must be compared to assess which procedure is optimal for each input. Crucially, Procedure A consists of two changes, while Procedure B consists of only one.

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6 Bennett (2012) and Houghton (2013) present similar cases involving the optimal choice between (′H) and (′LL). Note that Houghton (2013) also adopts Rawlins (2006) analysis of Mohawk.
(16) **Mohawk comparison of foot building procedures**

![Diagram]

In the following sections, we show that this is unproblematic for Parallel OT, in which changes apply simultaneously, but challenging for HS, in which changes apply successively.

### 2.3 Mohawk in Parallel OT

The Mohawk comparison of foot building procedures is straightforwardly expressed in Parallel OT, borrowing the approach from Rawlins (2006). We first motivate the analysis for stress and epenthesis separately, before moving onto their interaction. Definitions for the central constraints used here and in the appendix are given below. $\text{FTBIN(}\mu\text{)}$ expresses the preference for either of the left-headed, bimoraic feet (‘H) or (‘LL) (17a; Prince & Smolensky 1993/2004; the definition here from Rawlins 2006 and Broselow 2008).

(17) $\text{FTBIN(}\mu\text{)}$ Assign a violation for a foot with more or less than two morae.

$\text{FTHDL}$ demands alignment of the left edge of the foot head with the left edge of a foot, and $\text{FTHDR}$ demands alignment of the right edge of the foot head with the right edge of a foot (18a-b; e.g., Prince & Smolensky 1993/2004, McCarthy & Prince 1993a, Féry 1999, Rawlins 2006).
(18) a. FtHdL Assign a violation for every syllable intervening between the left edge of the foot head and the left edge of the foot.

b. FtHdR Assign a violation for every syllable intervening between the right edge of the foot head and the right edge of the foot.

While Mohawk is trochaic, (‘H) is generally preferred to (‘LL), as it satisfies both FtHdR and FtHdL (19). Assume that lower-ranked DEpμ is violated in the creation of (‘H) feet.

(19) | /CVCV/ | FtBin | FtHdL | FtHdR |
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>(‘CV:CV)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>(‘CV:CV)</td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td>(‘CV.CV)</td>
<td></td>
<td>*!</td>
</tr>
<tr>
<td>d.</td>
<td>(CV.CV)</td>
<td></td>
<td>*!</td>
</tr>
</tbody>
</table>

Note that FtHdL is omitted from the derivation of the comparison of procedures below, but assumed that FtHdL >> FtHdR captures the fact that (‘LL), rather than (L’L), surfaces in environments where (‘H) is ill-formed (e.g., where otherwise (‘H) would create a long epenthetic vowel; /te-k-rîk-s/ → [(‘te.ke)rîks], *[te(‘ke):rîks]). Note that additional constraints and rankings are assumed to account for other stress properties. Namely, NONFINALITY (the head foot of the prosodic word must not be final; Prince & Smolensky 1993/2004) >> ALIGN-R(Ft, PWd) >> ALIGN-L(Ft, PWd) accounts for the rightward orientation of the foot with respect to the word, modulo NONFINALITY (20).

(20) | /CVCVCV/ | NONFin | ALIGNR | ALIGNL |
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>a.</td>
<td>CVCV(‘CV:)</td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>CV(‘CV:)CV</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>c.</td>
<td>(‘CV:)CV.CV</td>
<td>**!</td>
<td></td>
</tr>
</tbody>
</table>

As for epenthesis, *COMPLEX >> DEpV and SYLLCON >> DEpV choose candidates with epenthesis into triconsonantal sequences (21) and oral consonant-sonorant sequences (22).

(21) | /CVCCCV/ | *COMPLEX | SYLLCON | DEpV |
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>a.</td>
<td>CV.CeC.CV</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>b.</td>
<td>CVC.CCV</td>
<td>*!</td>
<td></td>
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</tbody>
</table>

(22) | /CVCrV/ | *COMPLEX | SYLLCON | DEpV |
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</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>CV.Ce.rV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>CVC.rV</td>
<td></td>
<td>*!</td>
</tr>
</tbody>
</table>
We now account for the interaction between stress and epenthesis. Though we get (ˈH) by default through the monosyllabic footing and lengthening procedure, (ˈLL) surfaces when the former procedure would result in a long epenthetic vowel. We account for this with DepV:, which disprefers long epenthetic vowels (23). Hualde (1991), Kager (1999), Lombardi (2002), and de Lacy (2006), among others, argue that epenthetic vowels tend to display unmarked values. Assuming that long vowels are marked relative to short vowels, we expect that epenthetic vowels would be preferably short. This constraint captures the distribution of (ˈH) or (ˈLL), i.e. the comparison of footing procedures.

(23) DepV: Assign a violation for each long epenthetic vowel.

FtBIN, FtHdR, and DepV: are sufficient to express the Mohawk comparison of foot building procedures in Parallel OT. The comparison between footing procedures is expressed as follows. If an underlying vowel occupies an open penult, a monosyllabic foot is built and the tonic vowel lengthens (/k-haratat-s/ → [kha(ˈraː)tats]).

<table>
<thead>
<tr>
<th>/CVCCV/</th>
<th>DepV:</th>
<th>FtBIN</th>
<th>FtHdR</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. CV(ˈCV):CV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. CV(ˈCV)CV</td>
<td>*!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. (ˈCV.CV)CV</td>
<td></td>
<td></td>
<td>*!</td>
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</tbody>
</table>

If an epenthetic vowel occupies an open penult, a disyllabic foot is built, and no lengthening occurs (/te-k-rik-s/ → ['te.ˈk璃ks]). DepV: >> FtHdR prefers short epenthetic vowels over monosyllabic feet (25a~b), while FtBIN >> FtHdR rules out the monomoraic, monosyllabic foot (25a~c).

<table>
<thead>
<tr>
<th>/CVCCV/</th>
<th>DepV:</th>
<th>FtBIN</th>
<th>FtHdR</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. (ˈCV.Ce)CV</td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>b. CV(ˈCe):CV</td>
<td>*!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. CV(ˈCe)CV</td>
<td></td>
<td>*!</td>
<td></td>
</tr>
</tbody>
</table>

Thus, FtBIN, DepV: >> FtHdR elegantly captures the choice between two foot building procedures in Parallel OT. No ranking of these constraints, however, expresses the conspiracy in HS, as we will see in Section 2.4.

As a final remark, although we are primarily concerned with deriving (ˈH) and (ˈLL) in open penult forms, forms with underlying vowels (26) or epenthetic vowels (27) in a closed penult are trivially derived using the constraints already motivated. Neither profile could result in a long epenthetic vowel, and so (ˈH) surfaces in both cases:

---

8 Zimmermann (2017) finds that languages with phonemic vowel length contrasts may allow long and short epenthetic vowels, or only short epenthetic vowels, but never only long epenthetic vowels. DepV: may have phonetic grounding in reducing the perceptual distance between underlying and surface form (Steriade 2001/2008).
In this section, we show that if footing and lengthening take place in separate steps, as in HS, then no ranking of the aforementioned constraints successfully derives the distribution of the two footing procedures. We demonstrate this through a proof by contradiction (a methodology introduced in McCarthy 2010b): the ranking needed to derive forms undergoing one procedure contradicts the ranking needed to derive forms undergoing the other.

In HS, the default procedure monosyllabic footing and lengthening (/kaharat-t-s/ → [kha(ˈraː)tats]) takes two steps (cf. McCarthy 2008b, Pruitt 2012). First, a monomoraic (ˈL) foot is built (28a), then tonic vowel lengthening occurs (28b).

For CV(ˈCV)CV to win at Step 1, it must beat (ˈCV.CV)CV. Because the former has an (ˈL) foot while the latter (ˈLL), the former can only win if FtHdR outranks FtBin (29).

FtHdR >> FtBin was not entailed in the Parallel OT derivation, and seemingly contradicts the proposal that Mohawk feet are strictly bimoraic. Nonetheless, we can derive monosyllabic footing and lengthening in HS: in Step 2, FtBin correctly favors (30a).9

---

9 The demotion of FtBin below FtHdR is an instance of McCarthy, Pater, and Pruitt’s (2016) notion of the violation of the surface-true. Violation of the surface-true refers to the fact that, in HS, a constraint that is never violated by surface forms may have to be violated by intermediate forms, and consequently, demoted. This paper examines the consequences of violation of the surface-true for comparisons of procedures.
While monosyllabic footing and lengthening entails FtHDR >> FtBIN, disyllabic footing to avoid a long epenthetic vowel entails the opposite ranking (31). For the attested candidate (31b) to beat (31a), FtBIN must paradoxically rank above FtHDR.

<table>
<thead>
<tr>
<th>Step</th>
<th>/CVCeCV/</th>
<th>DEPV: FtHDR</th>
<th>FtBIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>1</td>
<td>CV(‘Ce)CV</td>
<td>*</td>
</tr>
<tr>
<td>b.</td>
<td>1</td>
<td>(‘CV.Ce)CV</td>
<td>*!</td>
</tr>
</tbody>
</table>

DEPV: cannot play the role of eliminating the monosyllabic candidate (31a), since the grammar cannot look ahead to see that subsequent lengthening would result in a long epenthetic vowel.10 Thus, footing and lengthening must apply in the same step in order to derive the distribution between the two footing procedures. That is, footing and lengthening are irrecursively parallel.

In sum, HS is unable to derive the distribution between heavy monosyllabic feet and disyllabic trochees because it cannot compare entire procedures. Parallel OT, on the other hand, can. In the appendix, we include further justification for the constraints used in our analysis, and Rawlins’ analysis more broadly. We show that FtBIN captures a broad conspiracy to ensure bimoraic feet observed in the interaction of stress with a variety of other processes in the language. We summarize a previous HS analysis of stress-epenthesis interaction in Mohawk (Elfner 2016), but show that it misses the broad generalization about foot binarity in the language.

3. The general form of a comparison of procedures

The Mohawk stress system is readily analyzable in Parallel OT but recalcitrant in HS. As mentioned in 2.2, this system is an instance of a COMPARISON OF PROCEDURES, defined in (31).

(31) To best satisfy a given set of constraints, the grammar:

by default, applies to the input procedure A, consisting of at least two changes;

INPUT $\rightarrow$ A$_1$ $\rightarrow$ A$_2$

but if the result is dispreferred, the grammar applies a different procedure, B.

INPUT $\rightarrow$ B$_1$

A nonempty set of DRIVER constraints (32a) drives the input to undergo one of Procedure A or Procedure B. Procedure A applies by default because a constraint *B disprefers Procedure B (32b). A BLOCKER constraint triggers B when A would create a dispreferred structure BLOCKER (32c). In Mohawk, FtBIN drives the two footing procedures. FtHDR generally prefers monosyllabic footing with lengthening over disyllabic footing. However, DEPV: blocks monosyllabic footing where it would create a long epenthetic vowel, and thus triggers disyllabic footing.

---

10 Assume DepV: could successfully assign a violation for a long epenthetic vowel if it showed up in any given step, even if this means the constraint can ‘look back’ to know that a given vowel is epenthetic (see Hauser, Hughto & Somerday 2016 for a proposal and defense of HS constraints of this type).
(32) a. **DRIVERS:** Assign a violation for not applying Procedure A or B

*Requires the application of Procedure A or B*

b. *B:* Assign a violation for the application of Procedure B

*Expresses default preference for Procedure A over B*

c. **BLOCKER:** Assigns a violation for application of Procedure A, in certain environments

*Expresses contextual preference for Procedure B over A*

These constraints express a comparison of procedures, depicted in (33). When a faithful mapping of some input would violate the **DRIVERS**, two candidates are compared — one in which A fully applied, and one in which B fully applied — with A chosen unless a blocking constraint prefers B, in which case B is chosen. More formally, an input \(x\) in some set of inputs \(X\) violates **DRIVERS**, and thus undergoes one of A or B. A generally applies to the inputs in \(X\), but for some proper subset of \(X\), applying A would violate **BLOCKER**. In these cases, B applies instead.\(^{11}\) All the cases discussed in this paper have this structure.

\[(33)\]

[Diagram: Decision tree for choosing between Procedure A and Procedure B based on the violation of **DRIVERS** and **BLOCKER**.

11 Though A must consist of at least two changes, B can consist of zero, one, or more changes. Furthermore, we note that A and B cannot have first changes that are identical. If they were, then in principle Procedure A could consist of \(A_1\) and \(A_2\), and Procedure B could consist of just \(A_1\). In such a case, the HS grammar can just decide whether to apply \(A_2\) in Step 2, and lookahead is not needed.
In the following subsections, we show that Parallel OT can express a comparison of procedures, while HS cannot. In Parallel OT, both of the Procedure A changes apply to the input in the same derivational step. Thus, the grammar can immediately assess whether the Procedure A candidate violates BLOCKER, and in the case that it does, it can select the Procedure B candidate. In HS, the Procedure A changes must take place one at a time. The grammar cannot look ahead to subsequent derivational steps to assess whether the result of fully applying Procedure A would violate BLOCKER, and so it cannot determine where Procedure A should apply, versus B.

### 3.1 Comparisons of procedures in Parallel OT

Recall that FtBIN, DEPV: >> FtHDR elegantly expresses the comparison between bimoraic feet in Mohawk in Parallel OT (see Section 2). These constraints and their ranking translates into the abstract comparison of procedures schema: by substituting FtBIN, DEPV: >> FtHDR for DRIVER, BLOCKER >> *B, we obtain the abstract result, as shown in tableaux (34) and (35) below. For readability, we provide the analogous Mohawk constraints and candidates in gray.

Suppose a constraint DRIVER triggers two inputs $x$ and $y$ to undergo one of Procedure A or Procedure B. $x$ undergoes Procedure A by default, mapping to $A_2(A_1(x))$ since $B_1(x)$ violates *B. Furthermore, suppose that $y$ undergoes Procedure B, mapping to $B_1(y)$, because otherwise Procedure A would result in $*A_2(A_1(y))$, which violates BLOCKER. The ranking DRIVER, BLOCKER >> *B accounts for the mapping $x \rightarrow A_2(A_1(x))$ (34). DRIVER is only satisfied by the full application of Procedure A, and so it eliminates $A_1(x)$ (along with the faithful candidate). Additionally, *B eliminates $B_1(x)$.

<table>
<thead>
<tr>
<th></th>
<th>$/x/$</th>
<th>DRIVER FtBIN</th>
<th>BLOCKER DEPV:</th>
<th>*B FtHDR</th>
</tr>
</thead>
<tbody>
<tr>
<td>(34) a.</td>
<td>$A_1(x)$</td>
<td>*!</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>kha(ˈra)tats</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>$A_2(A_1(x))$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>kha(ˈra)tats</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td>$B_1(x)$</td>
<td></td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(ˈkha.ra)tats</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**In the table:**
- Driver, BLOCKER >> *B also accounts for the mapping $y \rightarrow B_1(y)$ (35). BLOCKER >> *B favors applying Procedure B where the otherwise preferable Procedure A would violate BLOCKER (43).

---

12 In Section 2, we included in the discussion the constraint DEPM, violated in the process of applying default monosyllabic footing and lengthening. We leave it out here for purposes of brevity. It could be thought of as a *A constraint, ranked below *B, to express the general preference for Procedure A.

13 We abstract away from the faithful candidates $x$ and $y$ throughout this section, as they are not needed to illustrate our point. They could be eliminated by the same driving constraint that rules out $A_1(x)$ (e.g., an iterative spreading constraint), or by another driving constraint (e.g., in Mohawk, FtBIN does not eliminate the hypothetically faithful [kharatats], but WDSTRESS does (words must be stressed; cf. Ito & Mester 2016, McCarthy & Prince 1990)), or by *B in the case that the faithful candidate and $B_1(x)$ coincide (the Sino-Japanese case in Section 5.2, in which Procedure B is to do nothing). See Supplementary Materials for further discussion.
The analysis above thus captures the distribution between the two procedures. Procedures A and B are compared in the process of satisfying driving and blocking constraints. A, which consists of multiple changes to the input, applies by default, but if the full result of A were to violate a blocking constraint, then B applies as back-up.

3.2 Comparisons of procedures in HS

Though Parallel OT can capture comparisons of procedures, HS cannot. Again, suppose DRIVER motivates applying Procedure A or Procedure B to inputs x and y, such that x maps to A₂(A₁(x)), but y to B₁(y). In HS, the two Procedure A changes must apply in separate steps, and so x must map to A₁(x) before mapping to A₂(A₁(x)). Crucially, DRIVER is only satisfied by either applying both Procedure A changes or the one Procedure B change. A₁(x) does not satisfy DRIVER while B₁(x) does, and yet the former candidate must win over the latter. Hence DRIVER must be ranked below *B to ensure that A₁(x) wins in Step 1 (36). Then the second change of A can apply in Step 2 (37).

<table>
<thead>
<tr>
<th>Step</th>
<th>/x/</th>
<th>DRIVER</th>
<th>BLOCKER</th>
<th>*B</th>
<th>DRIVER</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>/kharatats/</td>
<td>A₁(x)</td>
<td>A₁(x)</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>a.</td>
<td></td>
<td>kha('ra)tats</td>
<td>kha('ra)tats</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td></td>
<td>B₁(x)</td>
<td>B₁(x)</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>('kha.ra)tats</td>
<td>('kha.ra)tats</td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step</th>
<th>/x/</th>
<th>DRIVER</th>
<th>BLOCKER</th>
<th>*B</th>
<th>DRIVER</th>
</tr>
</thead>
<tbody>
<tr>
<td>37</td>
<td></td>
<td>A₂(A₁(x))</td>
<td>A₂(A₁(x))</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>a.</td>
<td></td>
<td>kha('ra)tats</td>
<td>kha('ra)tats</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td></td>
<td>A₁(x)</td>
<td>A₁(x)</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>kha('ra)tats</td>
<td>kha('ra)tats</td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>
Since the selection of Procedure A over B requires DRIVER be demoted below *B, we have no way of capturing the fact that B applies whenever the result of A would violate BLOCKER. In the derivation with y, A₁ is wrongly predicted to apply (38).

<table>
<thead>
<tr>
<th>Step</th>
<th>/y/</th>
<th>BLOCKER</th>
<th>*B</th>
<th>DRIVER</th>
</tr>
</thead>
<tbody>
<tr>
<td>(38) a.</td>
<td>/wakeras/</td>
<td>DepV:</td>
<td>FtHdR</td>
<td>FtBin</td>
</tr>
<tr>
<td>1</td>
<td>♦️</td>
<td>A₁(y)</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>(waˈke)ras</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>♐️</td>
<td>B₁(y)</td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(ˈwa.ˈke)ras</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The HS derivation can only access the ill-formed result of A, *A₂(A₁(y)), after the pathological candidate A₁(y) is chosen over B₁(y). As was the case in Mohawk, a ranking paradox emerges: either *B is ranked above DRIVER so that Procedure A always applies, or *B is ranked below DRIVER so that Procedure B always applies — BLOCKER can play no role. This shows that HS cannot express a comparison of procedures: it cannot capture the fact that B applies only if the full result of A would violate BLOCKER. Hence, the assumption that the changes A₁ and A₂ apply in separate steps must be abandoned, so that the two are irreducibly parallel: they must take place in the same step of the derivation so that the grammar can compare the full result of Procedure A against other candidates. The validity of our proof was checked using OTWorkplace (Prince, Tesar & Merchant 2016), a computational implementation of Optimality Theory and Harmonic Serialism. The abstract inputs, outputs, and constraints presented in this section were fed into the program, and the results mirror the tableaux given above: while Parallel OT predicts languages with comparisons of procedures, HS excludes them. A summary of the OTWorkplace output is provided as supplementary materials.

Note that the general problem that comparisons of procedures present for HS is not resolved by switching from ranked constraints to weighted constraints in HS (cf. Kimper 2010a, Pater 2012); the weight of DRIVER must be lower than the weight of *B to ensure that x maps to A₁(x), but higher than the weight of *B to ensure that y maps to B₁(y). Thus, the same ranking paradox emerges.

The rest of the paper is devoted to showing that comparisons of procedures exist in a number of the world’s languages, and involve a diverse set of phonological processes. These cases can be treated in Parallel OT but are challenging for HS, suggesting a diverse array of processes necessitate irreducible parallelism.

### 4. Paradoxical reduplication and glide formation in Maragoli

Maragoli, a Bantu language spoken primarily in Kenya, presents evidence of lookahead in a reduplication-repair interaction. Copying and hiatus repair in the language apply in whichever order results in a simplex onset. Thus, the decision to copy before or after hiatus repair depends on the final result of choosing either option. We summarize the case below, but for the full set of data, thorough analysis of them, and evidence for their psychological reality, see Zymet (2016).

14 We thank Nazarré Merchant for his assistance on this matter.
4.1 The data

The Maragoli data were obtained from a native Maragoli speaker in a UCLA Field Methods class in the winter of 2015. Some of the data below are also given in Leung (1991). In all cases where a form obtained in the class was also found in Leung (1991), the match was perfect.

Maragoli has two productive, entirely systematic hiatus repairs: glide formation (39a-d) and low vowel deletion (40a-b). We illustrate the processes as they apply to various noun class and noun class agreement prefixes in the language. Glide formation applies to the agreement prefixes given below when they come before vowels (39a-d). /i e/ and /o u/ surface as [j] and [w], respectively, neutralizing the height contrast between the vowel pairs.15

Glide formation

(39a) vi-ra vj-a:ŋge (/vi-ange/) (39b) e-ra j-a:ŋge (/e-ange/)
AGR8-this AGR8-my AGR9-this AGR9-my

(39c) mu-ra mw-a:ŋge (/mu-ange/) (39d) go-ra gw-a:ŋge (/go-ange/)
AGR18-this AGR18-my AGR3-this AGR3-my

Low vowel deletion, for example, applies to the noun class and noun class agreement prefixes in (40a-b), so that /a/ elides before vowels:

Low vowel deletion

(40a) ma-du:ma m-u:va (/ma-uva/) (40b) ga-ra g-e:tu (/ga-etu/)
NCL6-corn NCL6-sun AGR6-this AGR6-Ipl.POSS

In addition to hiatus repair, the language also has a process of reduplication to mark second- and third-person possessive categories in the language.16, 17 (41) displays examples of the possessive paradigm. Second- and third-person singular possessives are characterized by a one-to-many mapping between meaning and form: possession is exponed as both a reduplicative prefix and a fixed-segment suffix (see Stonham 1994, Downing & Inkelas 2015 for a similar pattern in Nitinaht, and Hyman 1999 for the same pattern in Kalanga).

15 In hiatus repairs in the language, the surviving vowel undergoes compensatory lengthening unless it is word-final. In this case, lengthening is blocked (e.g., (/vi-al, /vja) = AGR8-of). In the data presented below, the vowel surviving hiatus repair is always final, so compensatory lengthening will play little role in the following discussion.

16 The nearby Tarok (Robinson 1976) and Kalanga (Hyman 1999), and the Oceanic language Arosi (Lynch & Horoi 2002), also use reduplication to mark possessive categories; see Bogoras 1969, Dunn 1999, Rubino 2004, Inkelas 2014 a.o. for other languages where reduplication is used to mark plurality, tense, various aspectual distinctions, and other inflectional categories.

17 Other paradigms lend evidence to reduplication exponing possession, rather than occurring to satisfy a length requirement (cf. Yu 2005, Inkelas 2008). For example, in demonstratives associated with near objects, echo epenthesis, commonly associated with compensatory reduplication (Yu 2005), applies in forms that would otherwise surface as a monosyllable (e.g., /ga/ → [a-ga], ‘this (class 7)’; /ke/ → [e-ke], ‘this (class 7)’; /ga+ɔ/ → [a-g-ɔ] ‘that (class 6); /ke+ɔ/ → [e-tʃ-ɔ] ‘that (class 6); cf. Leung 1991). Far-object demonstratives indicate the epenthetic vowel cannot simply be associated with demonstrative status, e.g. [ga-no] = ‘this (far, class 6)’ (Leung 1991).
To demonstrate the lookahead phenomenon in Maragoli possessive forms, it suffices to examine the behavior of only the second-person forms. We set aside third-person forms for purposes of brevity. Before presenting the data, we motivate underlying forms for second-person possessives.

We begin by justifying that the copied material is the initial morpheme rather than the second. Consider the data in (42a-b):

(42a) \[\text{RED-AGR8-2sg.POSS} \rightarrow \text{[vi:-vj-ɔ]}\]
(42b) \[\text{RED-AGR9-2sg.POSS} \rightarrow \text{[jɔ:-j-ɔ]}\]

In the class 8 possessive \[\text{[vi:-vj-ɔ]}\], we find two instances of the class 8 agreement prefix, the latter of which has undergone glide formation before a stem vowel. \[\text{[vi:-vj-ɔ]}\] alone does not reveal which instance is the original and which is the copy: the copied material is located either initially or medially. But in the class 9 possessive \[\text{[jɔ:-j-ɔ]}\], we find two instances of the glided class 9 agreement prefix and two instances of the stem vowel: the copied material is located initially or finally. To reconcile these observations, we can say that the copied material is located initially. Following McCarthy & Prince (1986/1996), we assume that copied material is copied into reduplicants (RED): morphemes consisting of empty prosodic templates present in the input. Thus, we posit the underlying forms shown in (43a-b).

(43a) \[\text{RED-AGR8-your} \rightarrow \text{[vi:-vj-ɔ]}\]
(43b) \[\text{RED-AGR9-your} \rightarrow \text{[jɔ:-j-ɔ]}\]

(44) displays the general structure of the second person possessives.

(44) \[\text{RED-AGR-ɔ/}\]

In (45), we present a subset of second-person singular possessives. We find that possessives can combine with a substantial variety of agreement prefixes in such a way that reduplication interacts with hiatus repair in intricate, but nevertheless systematic, ways. Again, for the full set of second-person and third-person possessives, see Zymet (2016).

---

\[\text{18} \] Since all reduplicated forms occur in tandem with hiatus repair, it is impossible to show reduplication in isolation.

\[\text{19} \] If the reduplicant were medial, for example, it would be a mystery how \[\text{[jɔ:-j-ɔ]}\] could be derived from \[\text{/e-RED-ɔ/}\]; if it were final, it would be a mystery how \[\text{[vi:-vj-ɔ]}\] could be derived from \[\text{/vi-ɔ-RED/}\].
Examples with glide formation

<table>
<thead>
<tr>
<th>Noun class</th>
<th>Agmt. prefix</th>
<th>Ex. with prefix</th>
<th>2sg poss.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>/o/-</td>
<td>o-ra, ‘this’</td>
<td>wɔː:v-ɔ</td>
</tr>
<tr>
<td>3</td>
<td>/go/-</td>
<td>go-ra, ‘this’</td>
<td>gu:-gw-ɔ</td>
</tr>
<tr>
<td>5</td>
<td>/ri/-</td>
<td>ri-lahe, ‘pretty’</td>
<td>ri:-rj-ɔ</td>
</tr>
<tr>
<td>8</td>
<td>/vi/-</td>
<td>vi-ra, ‘this’</td>
<td>vi:-vj-ɔ</td>
</tr>
<tr>
<td>9</td>
<td>/e/-</td>
<td>e-ra, ‘this’</td>
<td>jɔ:-j-ɔ</td>
</tr>
<tr>
<td>10</td>
<td>/zi/-</td>
<td>zi-ra, ‘this’</td>
<td>zi:-zj-ɔ</td>
</tr>
<tr>
<td>11</td>
<td>/ro/-</td>
<td>ro-ra, ‘this’</td>
<td>ru:-rw-ɔ</td>
</tr>
<tr>
<td>13</td>
<td>/to/-</td>
<td>to-ra, ‘this’</td>
<td>tu:-tw-ɔ</td>
</tr>
<tr>
<td>14</td>
<td>/vo/-</td>
<td>vo-ra, ‘this’</td>
<td>vu:-vw-ɔ</td>
</tr>
<tr>
<td>15</td>
<td>/ko/-</td>
<td>ko-ra, ‘this’</td>
<td>ku:-kw-ɔ</td>
</tr>
<tr>
<td>18</td>
<td>/mu/-</td>
<td>mu-ra, ‘this’</td>
<td>mu:-mw-ɔ</td>
</tr>
</tbody>
</table>

Examples with low vowel deletion

<table>
<thead>
<tr>
<th>Ex. with prefix</th>
<th>2sg poss.</th>
</tr>
</thead>
<tbody>
<tr>
<td>va-ra, ‘this’</td>
<td>vɔː:v-ɔ</td>
</tr>
<tr>
<td>ga-ra, ‘this’</td>
<td>gaː:g-ɔ</td>
</tr>
<tr>
<td>ka-ra, ‘this’</td>
<td>kɔ:-k-ɔ</td>
</tr>
<tr>
<td>ha-ra, ‘this’</td>
<td>hɔ:-h-ɔ</td>
</tr>
</tbody>
</table>

Before moving onto the full analysis, we briefly describe the data above and their properties. First, note that the copied vowels are all long. This can be accounted for by specifying that the reduplicant is heavy, following Hayes & Abad (1989) and McCarthy et al. (2012)’s approach to an identical pattern found in Ilokano. As for specifics of the glide formation cases, in examples with CV- prefixes such as (46a) below, the prefix is copied into the reduplicant, and the base hiatus undergoes glide formation. Note that the copied vowel always surfaces as high, even if the prefix is underlyingly mid (e.g., RED-go-ɔ/, [gu:-gw-ɔ] = RED-AGR3-your) — a fact we will account for in the analysis later. In glide formation examples with V- prefixes such as in (46b), the prefix undergoes glide formation, and the entire resulting base is copied. As for low vowel deletion examples such as in (46c), the prefix vowel is deleted and the entire resulting base is copied.

Representative examples

(46a) /RED-vi-ɔ/ → [vi:-vj-ɔ]  (46b) /RED-e-ɔ/ → [jɔ:-j-ɔ]  (46c) /RED-ga-ɔ/ → [gaː:g-ɔ]

RED-AGR8-your  RED-AGR9-your  RED-AGR6-your

20 A merely apparent alternative approach is to say that length is a remnant of compensatory lengthening following hiatus repair in the base. For example, we could envision the following schematic, simplified derivation for [jɔ:-j-ɔ]: RED-e-ɔ → RED-j-ɔ (glide formation with compensatory lengthening) → jɔ:-j-ɔ (copying) → jɔ:-j-ɔ (final vowel shortening). But [vi:-vj-ɔ] and like forms deriving from C[i e] - prefixes provide evidence against this approach; the copied vowel is long, but does not derive from a lengthened vowel in the base.

21 In the other V- case, /RED-o-ɔ/, [wɔː:v-ɔ], the base prefix undergoes vowel hardening, surfacing as [v] between vowels. See Zymet (2016) for the complete descriptive and explanatory account.
The central arguments here are that the account of Maragoli possessives involves a comparison of procedures, and thus necessitates that reduplication and hiatus repair apply in parallel. In particular, the copying-before-repair derivation is compared against the repair-before-copying derivation to determine which of the two results in a well-formed onset. We illustrate the issue in (47a-b) using informal, schematic derivations of two forms involving reduplication and glide formation, (/RED-vi-ɔ/, [vi:-vj-ɔ]) and (/RED-e-ɔ/, [jɔ:-j-ɔ]). In (47a), glide formation must take place before copying on the one hand to derive [jɔ:-j-ɔ] from vowel-initial /RED-e-ɔ/. This avoids the onsetless reduplicant in *[e:-j-ɔ].

\[(47a)\]

\[
\begin{array}{ccc}
\text{UR} & \text{Glide Formation} & \text{Copying} \\
\text{RED-e-ɔ} & \text{RED-j-ɔ} & \text{e:-e-ɔ} \\
\text{SR} & \checkmark [jɔ:-j-ɔ] & \checkmark [jɔ:-j-ɔ] \\
\end{array}
\]

In (47b), on the other hand, copying must take place before glide formation, to derive [vi:-vj-ɔ] from consonant-initial /RED-vi-ɔ/. This avoids the extra complex onset in *[vjɔ:-vj-ɔ].

\[(47b)\]

\[
\begin{array}{ccc}
\text{UR} & \text{Glide Formation} & \text{Copying} \\
\text{RED-vi-ɔ} & \text{RED-vj-ɔ} & \text{vi:-vi-ɔ} \\
\text{Copying} & \text{vjo:-vjo-ɔ} & \text{vi:-vj-ɔ} \\
\text{SR} & \checkmark [vjɔ:-vj-ɔ] & \checkmark [vi:-vj-ɔ] \\
\end{array}
\]

The Maragoli pattern constitutes a comparison of procedures. Hiatus repair followed by copying applies to the input, unless the result is a complex onset; in such a case, copying applies first, then repair. Note that Maragoli adds to the breadth of cases of the emergence of the unmarked (McCarthy & Prince 1994), in the sense that consonant-glide onsets are avoided in reduplicants but allowed in stems (cf. Steriade 1988, Hayes & Abad 1989 on onset-skipping). We focus on possessives with glide formation below, but return possessives with low vowel deletion (e.g., /RED-ga-ɔ/, [gɔ:-g-ɔ]) in Section 4.3.

### 4.2 Maragoli in Parallel OT

In Parallel OT, reduplicative possessives are easy to capture: copying and hiatus repair apply in the same stage, in whichever way best satisfies onset well-formedness constraints. In particular, the grammar applies repair followed by copying, i.e. the full copying procedure (e.g., /RED-e-ɔ/, [jɔ:-j-ɔ]); but if this were to produce a second complex onset, then the grammar applies copying followed by repair, i.e. the partial copying procedure (e.g., /RED-vi-ɔ/, [vi:-vj-ɔ], *[vjɔ:-vj-ɔ]). The data are treated straightforwardly through markedness constraints and base-reduplicant correspondence (BR-correspondence; see McCarthy & Prince 1995, 1997 for an introduction) (48). NoHIATUS and MAX-BR drive hiatus repair and copying. Note that MAX-BR also serves as *B, as it militates against the partial copying procedure. *COMPLEX is the BLOCKER, triggering partial copying where full copying would produce an extra complex onset.

---

22 Though ONSET would work just as well for our purposes, see Orie & Pulleyblank (1998) for an argument for NoHIATUS in particular for handling hiatus repairs.
(48) **Drivers:**
- **NoHiatus:** Assign a violation for each sequence of adjacent vowels.
- **Max-BR:** Assign a violation for every base segment that lacks a reduplicant correspondent.

*B:* **Max-BR:** (Disfavors partial copying.)

**Blocker:**
- **Complex:** Assign a violation for each complex margin.

The tableaux below illustrate how glide formation and reduplication interact in the selection of (/RED-vi-ɔ/, [vi:-vj-ɔ]) and (/RED-e-ɔ/, [jɔ:-j-ɔ]). MAX-BR favors full copying (49), but *Complex >> MAX-BR favors partial copying where full copying would result in an extra complex onset (50). Assume that low-ranking IDENT-IO, not shown below, is violated by applying glide formation.

<table>
<thead>
<tr>
<th>Driver</th>
<th>Blocker</th>
<th>*B</th>
</tr>
</thead>
<tbody>
<tr>
<td>/RED-e-ɔ/</td>
<td>NoHiatus</td>
<td>*Complex</td>
</tr>
<tr>
<td>a.</td>
<td>eː1-l1-ɔ2</td>
<td><em>!</em></td>
</tr>
<tr>
<td>b.</td>
<td>eː1-j1-ɔ2</td>
<td>*!</td>
</tr>
<tr>
<td>c.</td>
<td>j1ɔː2-j1-ɔ2</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Driver</th>
<th>Blocker</th>
<th>*B</th>
</tr>
</thead>
<tbody>
<tr>
<td>/RED-vi-ɔ/</td>
<td>NoHiatus</td>
<td>*Complex</td>
</tr>
<tr>
<td>a.</td>
<td>v1iː2-v1iː2-ɔ3</td>
<td>*!</td>
</tr>
<tr>
<td>b.</td>
<td>v1iː2-v1jɔ2-ɔ3</td>
<td>*</td>
</tr>
<tr>
<td>c.</td>
<td>v1jɔː2-ɔ3-v1jɔ2-ɔ3</td>
<td>**!</td>
</tr>
</tbody>
</table>

Here we see that reduplication and repair apply in a way that best satisfies the Driver constraints, which drive hiatus repair and reduplication, and Blocker constraints, which demand well-formed syllables. By default, the repair-reduplication order is applied, but where the default would create a suboptimal reduplicant onset, the reduplication-repair order is chosen instead. In this way, Parallel OT can express the generalization that reduplication and glide formation apply in whichever order yields optimal surface onsets.

### 4.3 Maragoli in Harmonic Serialism

McCarthy, Kimper & Mullin (2012) propose a sub-framework within HS, Serial Template Satisfaction, which captures patterns of reduplication and their interaction with phonology. Following McCarthy & Prince (1986/1996), Serial Template Satisfaction posits reduplicant morphemes, i.e. empty prosodic templates in the input. Many constraint-based analyses in the past

---

23 Forms such as (/RED-go-ɔ/, [g1uː2-g1w2-ɔ3]) have the same correspondence relations as [viː2-vjɔ2-ɔ3], but are special in that the reduplicant surfaces high even though the UR prefix vowel is mid. This can be captured with IDENT-BR(high), which drives the reduplicant vowel to match its corresponding glide for quality (Zymet 2016). An alternative would be to posit that mid, tense vowels are generally illicit, but preserved in roots, by positing e.g. IDENT-IO ≫ *[-high, +tense]. Though HS lacks BR-correspondence, it seemingly could rely on *[-high, +tense].
have posited base-reduplicant correspondence to drive copying, but because correspondence plays no role in HS, Serial Template Satisfaction instead employs HEADEDNESS (abbreviated HD in tableaux; Selkirk 1995; 51 below).

51) **HEADEDNESS:** Assign a penalty for every syllable that does not contain a segment as its head.

We thus compare the parallel OT account and HS account with the same constraints, except that we substitute MAX-BR for HD.

To get repair followed by copying as in (/RED-e-ɔ/, [jɔ::j-ɔ]), we must rank NOHIATUS above HD (52).

<table>
<thead>
<tr>
<th>Step</th>
<th>/RED-e-ɔ/</th>
<th>Driver</th>
<th>Blocker</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>RED-j-ɔ</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>e::e-ɔ</td>
<td>*!</td>
<td></td>
</tr>
</tbody>
</table>

But now since NOHIATUS ranks above HD, we can never get the opposite order, namely the reduplication-repair order. To derive [vi::vj-ɔ] from /RED-vi-ɔ/, HD must be ranked above NOHIATUS so that copying applies before glide formation (54). The situation is analogous to the ordering paradox observed in the rule-based derivations: changes driven by HD and NOHIATUS cannot be applied in a fixed series, since both orders are required for the full paradigm. HS misses the generalization that reduplication and repair apply in whichever order yields a simplex onset — prosodic constraints such as *COMPLEX play no role.

<table>
<thead>
<tr>
<th>Step</th>
<th>/RED-j-ɔ/</th>
<th>Driver</th>
<th>Blocker</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>RED-j-ɔ</td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>jɔ::j-ɔ</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note that we cannot employ an ONSET constraint ranking higher than HD to eliminate the first step candidate \e::e-ɔ\ as in (52b), since then it would eliminate \vi::vi-ɔ\ (54b), a desired first step winner.

We again arrive at a situation where we must demote a DRIVER below *B, resulting in only one procedure ever applying. The HS account fails to treat the distribution between the repair-reduplication procedure on one hand, and reduplication-repair on the other. Thus, reduplication
and repair are irreducibly parallel: the two must fully apply in the same derivational step in order to capture the distribution between the two conspiring procedures. For the full set of reduplicative possessives and an in-depth analysis of them, and for refutations of apparent counteranalyses, see Zymet (2016).

4.4 Reduplication applies in parallel with hiatus repairs in general

This section argues that hiatus repair in general, in particular both glide formation and low vowel deletion, must apply in parallel with reduplication, or else we fail to capture the broad generalization that these repairs, though diverse, militate against the same output structure: adjacent vowel pairs.

Constraint-based accounts of diverse repairs in Bantu and beyond utilize a single NOHIATUS constraint as well as a set of lower-ranked faithfulness constraints to determine the repair for a particular hiatus (Rosenthal 1994; Casali 1995, 1997, 1998; Orie & Pulleyblank 1998; Senturia 1998; Baković 2007). This captures the fact that the various repairs all conspire to avoid adjacent vowels from surfacing. In Maragoli, we can account for glide formation and low vowel deletion using a single driving constraint, NOHIATUS, together with the constraints in (55):

\[(55)\] IDENT(syl): Assign a violation for each output segment differing from its input correspondent in the value of [syllabic].

MAXV: Assign a violation for each input vowel lacking an output correspondent.

* ː Assign a violation for each instance of a glided [a].

We can capture glide formation in \(/v\text{-}a\text{n}g\varepsilon/\), \([v\text{j-aː}ng\varepsilon]\) = AGR8-my) and low vowel deletion in \(/m\text{-}u\text{v}a/\), \([m\text{-}u\text{ː}v\text{a}]\), NCL6-sun), with the ranking NOHIATUS, * ː >> MAXV >> IDENT(syl). Glide formation applies by default (56), but where [ŋ] would surface as a result, deletion applies (57).24

\[(56)\]

<table>
<thead>
<tr>
<th>/v\text{-}a\text{n}g\varepsilon</th>
<th>NOHIATUS</th>
<th>* ː</th>
<th>MAXV</th>
<th>IDENT(syl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. v\text{-}a\text{n}g\varepsilon</td>
<td>*!</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. v\text{j-aː}ng\varepsilon</td>
<td></td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>c. v\text{-}a\text{ŋ}v\varepsilon</td>
<td></td>
<td></td>
<td>*!</td>
<td></td>
</tr>
</tbody>
</table>

\[(57)\]

<table>
<thead>
<tr>
<th>/m\text{-}u\text{v}a/</th>
<th>NOHIATUS</th>
<th>* ː</th>
<th>MAXV</th>
<th>IDENT(syl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. m\text{-}u\text{v}a</td>
<td>*!</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. m\text{a-}u\text{v}a</td>
<td></td>
<td>*!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. m\text{-}u\text{ː}v\text{a}</td>
<td></td>
<td></td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

Using quality-specific constraints such as *aV and *(i e o u)V to treat low vowel deletion and glide formation here is possible, but would fail to capture the hiatus conspiracy here: namely, that glide formation and low vowel deletion both militate against adjacent vowel pairs.

24 See Zymet (2016) for the OT treatment of compensatory lengthening in these cases.
In reduplicative possessives with low vowel deletion such as (/RED-gaː/, [gɔː-g-ɔ]), hiatus repair applies to the base first, and the full result is copied (/RED-gaː/ → RED-g-ɔ → gɔː-g-ɔ = [gɔː-g-ɔ]). We saw before that in glide formation examples with CV- prefixes such as the class 8 possessive (/RED-viː/, [viː-vj-ɔ]), we need hiatus repair to apply after copying (/RED-viː/ → viː-vi- → viː-vj-ɔ = [viː-vj-ɔ]). We will see that while Parallel OT can capture these data using only NoHIATUS, HS cannot. The latter framework can only capture the different orders of hiatus repair by appealing to *AV and *[i e o u]V. This reanalysis misses the broad generalization that hiatus repairs conspire to prevent hiatus.

We present the Parallel OT account of possessives with glide formation and possessives with low vowel deletion. Below we make use of the same constraints as before: NoHIATUS, MAX-BR, and *COMPLEX. With these constraints we easily get hiatus repair and full copying in (/RED-gaː/, [gɔː-g-ɔ]) as in (58), but *COMPLEX >> MAX-BR favors partial copying in (/RED-viː/, [viː-vj-ɔ]) where full copying would result in an extra complex onset (*[vjː-vj-ɔ]) (59). Assume low ranking IDENT(syl) and MAXV are violated in applying glide formation and low vowel deletion respectively.

<table>
<thead>
<tr>
<th>DRIVER</th>
<th>BLOCKER</th>
<th>*B</th>
</tr>
</thead>
<tbody>
<tr>
<td>/RED-gaː/</td>
<td>NoHIATUS</td>
<td>*COMPLEX</td>
</tr>
<tr>
<td>a.</td>
<td>giaː2-gia2-ɔ3</td>
<td>*!</td>
</tr>
<tr>
<td>b.</td>
<td>giaː2-gia-ɔ2</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DRIVER</th>
<th>BLOCKER</th>
<th>*B</th>
</tr>
</thead>
<tbody>
<tr>
<td>/RED-viː/</td>
<td>NoHIATUS</td>
<td>*COMPLEX</td>
</tr>
<tr>
<td>a.</td>
<td>viː2-viː2-ɔ3</td>
<td>*!</td>
</tr>
<tr>
<td>b.</td>
<td>viː2-viː2-ɔ3</td>
<td>*</td>
</tr>
<tr>
<td>c.</td>
<td>vij2ɔː-vij2-ɔ3</td>
<td>**!</td>
</tr>
</tbody>
</table>

In HS, we again use the same constraints, except that the driving constraint MAX-BR is replaced with the similar constraint HD. Hiatus repair must come before copying to derive (/RED-gaː/, [gɔː-g-ɔ]). Thus, we must rank HD below NoHIATUS (60).

<table>
<thead>
<tr>
<th>Step</th>
<th>/RED-gaː/</th>
<th>*B</th>
<th>DRIVER</th>
<th>BLOCKER</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>RED-g-ɔ</td>
<td>*!</td>
<td>NoHIATUS</td>
<td>*COMPLEX</td>
</tr>
<tr>
<td>b.</td>
<td>gaː-gaː</td>
<td>*!</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

23
But now, since NoHiatus ranks above HD, we cannot derive reduplication-repair order in forms like (/RED-vi-ɔ/, [viː-vj-ɔ]) (62).

To derive [viː-vj-ɔ] from /RED-vi-ɔ/, HD must be ranked above NoHiatus so that copying applies before hiatus repair. But then [gɔː-g-ɔ] cannot be derived from /RED-ga-ɔ/, as hiatus repair must apply before copying. To dispel the paradox, one might be compelled to break NoHiatus into quality-specific constraints such as *aV and *(i e o u)V, ranking *aV above HD to ensure that vowel deletion applies before copying, and HD above *(i e o u)V to ensure glide formation applies after copying. Adding these constraints alone still fails to derive cases like (/RED-e-ɔ/, [jɔː-j-ɔ]), which require that glide formation apply before copying. Moreover, the decision to abandon NoHiatus for quality-specific constraints misses the generalization that hiatus repairs, though diverse, militate against the same broad configuration: adjacent vowel pairs. If we wished to capture this generalization, then reduplication and broad hiatus repair — that is, reduplication, glide formation, and low vowel deletion — are irreducibly parallel.

Summing up, we find that the Maragoli system involves comparing two procedures — the reduplication-repair order and the repair-reduplication order — and the procedure chosen is the one that best satisfies onset well-formedness constraints of the fully formed reduplicant. Parallel OT treats these data naturally, while HS fails in the same way that it did for the Mohawk system. A reanalysis that posits quality-specific constraints misses the broad generalization that hiatus repairs conspire against the same output structure, vowel hiatuses.

5. Additional cases requiring irreducible parallelism

In addition to the Mohawk stress and Maragoli reduplication systems, a number of other phenomena with analyses already developed and extensively defended turn out to involve comparisons of procedures. We discuss in particular assimilation and epenthesis in Lithuanian (Baković 2005, Albright & Flemming 2013), and Sino-Japanese root fusion (e.g., Kurisu 2000, Kawahara et al. 2003, Ito & Mester 2015). We also briefly discuss nasal spreading and deletion in Gurindji (Stanton 2016) and footing, metathesis, and syncope in Maltese (Anderson 2016). These cases all necessitate irreducible parallelism, and thus suggest that derivational lookahead is not merely a property associated with particular phonological processes (McCarthy 2010b), but with the grammar as a whole.
5.1 Lithuanian assimilation—epenthesis

In Lithuanian, the verbal prefixes *ap-* and *at-* (63a) generally assimilate in voicing and palatality to following obstruents (63b), except when full assimilation would produce a geminate. In such a case, epenthesis applies instead, with concomitant palatalization before [i] (63c). (See Pająk & Baković 2010 for a similar pattern in Polish.) Baković develops an analysis of these data in Parallel OT, and Albright & Flemming (2013) shows that the analysis cannot be replicated in HS. We show why this is the case: the analysis is an instance of a comparison of procedures.

<table>
<thead>
<tr>
<th>Faithful forms (63a)</th>
<th>Assimilated forms (63b)</th>
<th>Epenthetic forms (63c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ap-rafį:tįi, ‘to describe’</td>
<td>ab-gautįi, ‘to deceive’</td>
<td>ap:i-baršti (ab-barsči), ‘to spill on’</td>
</tr>
<tr>
<td>ap-taršti, ‘to describe’</td>
<td>ap1-temšti:šti, ‘to obscure’</td>
<td>ap1-béršti (ab1-bersči), ‘to strew’</td>
</tr>
<tr>
<td>at-kopšti, ‘to rise’</td>
<td>ad-gautśti, ‘to get back’</td>
<td>at1-duotsči (ad-dotsiči), ‘to give back’</td>
</tr>
<tr>
<td>at-rasšti, ‘to find’</td>
<td>at1-pšautśti, ‘to cut off’</td>
<td>at1-dėtsči (ad1-detsči), ‘to delay’</td>
</tr>
<tr>
<td></td>
<td>ad1-bšešti:šti, ‘to run up’</td>
<td></td>
</tr>
</tbody>
</table>

Baković’s account uses the constraints in (64). The AGREE constraints drive agreement between adjacent obstruents, DEP disfavors epenthesis, and NoGEM prevents geminates from surfacing.

(64) **Driver:**

- **AGREE[voi]** Assign a violation for every pair of adjacent obstruents with different specifications for [voice]
- **AGREE[pal]** Assign a violation for every pair of adjacent obstruents with different specifications for [palatal]

- **B:**
  - **DEP** Assign a violation for every segment in the output that lacks a correspondent in the input

**Blocker:**

- **NoGEM** Assign a violation for two adjacent identical segments

AGREE[voi], AGREE[pal] >> DEP drives assimilation, with DEP eliminating the candidate that resolves agreement through epenthesis (65). NoGEM >> DEP, however, chooses the candidate that resolves agreement through epenthesis in environments where full assimilation would yield a geminate (66). Assume DEP ranks above a constraint like IDENT, to express the preference to satisfy AGREE through assimilation over epenthesis.

<table>
<thead>
<tr>
<th>DRIVER</th>
<th>DRIVER</th>
<th>BLOCKER</th>
<th>*B</th>
</tr>
</thead>
<tbody>
<tr>
<td>/p-dš/</td>
<td>AGREE[voi]</td>
<td>AGREE[pal]</td>
<td>NoGEM</td>
</tr>
<tr>
<td>o.</td>
<td>p-dš</td>
<td>*!</td>
<td>*!</td>
</tr>
<tr>
<td>b.</td>
<td>pši-dš</td>
<td></td>
<td>*!</td>
</tr>
<tr>
<td>c.</td>
<td>bšl-dš</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

25
HS cannot capture the distribution of assimilation and epenthesis using Baković’s constraints, given that voicing and palatalization assimilation apply in separate steps (Albright & Flemming 2013). Assimilation requires two steps to satisfy both AGREE constraints, while epenthesis requires only one. Thus, for assimilation to ever apply, at least one of the AGREE constraints must be demoted below NoGem (67). Here again we see the necessity to demote a DRIVER below *B to express the default procedure.

The result is that epenthesis will never apply; because HS cannot look ahead to determine if full assimilation would violate NoGem, it cannot block it from applying (68).

As long as voicing assimilation and palatalization assimilation cannot occur in a single step, HS fails to capture Lithuanian agreement. In this way, the assimilatory processes are irreducibly parallel.

One might be tempted to give an HS analysis of epenthesis here in terms of avoidance of sufficiently similar adjacent segments, rather than in terms of geminate avoidance. If, for instance, NoGem were replaced with a constraint disfavoring sequences like [pjbj] or [bb], then epenthesis could apply instead of assimilation in step 1, in cases where full assimilation would yield a geminate. This reanalysis misses a broad, crosslinguistic generalization: Baković (2005) crucially shows that the features that epenthesis ignores for the sake of breaking up sufficiently similar segments are voicing and palatalization, the very same features that are involved in assimilation in the language. Baković shows that this property of identity avoidance — the features ignored for purposes of antigemination are those that assimilate independently in the language — holds across a significant variety of languages (see also Pająk & Baković 2010 for additional evidence from Polish on the tight relationship between assimilation and antigemination). Baković argues that the
relationship between assimilation and antigemination is captured if \textsc{con} only includes \textsc{agree} constraints, which drives assimilation, and \textsc{nogem}, which drives antigemination where assimilation would result in a geminate. A reanalysis in terms of constraints against sequences like \{p'b\} or \{bb\} dismisses this generalization as coincidence.

5.2 Sino-Japanese root fusion

In Sino-Japanese, CVCV roots are commonly compounded together by a procedure called root fusion (Ito 1986, Tateishi 1989, Ito & Mester 1996). Representative forms from Ito & Mester (1996) are given in (69) and (70). The boundary-adjacent vowel deletes, and the resulting consonant cluster undergoes gemination (69a, 70a). But whenever this would produce a voiced geminate, the compound surfaces faithfully (69b, 70b).

\begin{verbatim}
(69)   betu      different  |  (70)   niti       sun
      a. bek-kaku different style |
            bes-soo separate mail |
            betu-bin separate carrier |
            betu-goo separate issue |
            (*bep-bin) |
      b. betu-bin separate |
            (*beep-bin) |
      b. betu-goo separate issue |
            (*beep-goo) |
\end{verbatim}

The system has been analyzed extensively in Parallel OT (e.g., Kurisu 2000, Kawahara et al. 2003, Ito & Mester 2015), but not in HS. As we will see, HS is unable to capture the data using the constraints previously developed and argued for. The analysis involves a comparison of procedures: apply syncope and geminatio unless the result is a voiced geminate; in such a case, do nothing.

For the Parallel OT analysis, we adopt the constraints given in Kurisu (2000) (71). Fusion reflects a drive towards small prosodic words and a drive away from clusters disagreeing in place, and is expressed by the driving constraints \textsc{codacond} and \textsc{align}(\textsc{syll}, \textsc{prwd}, \textsc{l}). Defaulthood of fusion is already enforced by the fact that the auxiliary procedure, doing nothing, fails to satisfy \textsc{align}(\textsc{syll}, \textsc{prwd}, \textsc{l}); hence \textsc{b} is also to be \textsc{align}(\textsc{syll}, \textsc{prwd}, \textsc{l}). Finally, the blocking constraint is \textsc{voigem}, violated when fusion results in a voiced geminate.

\begin{verbatim}
(71)  \textbf{drivers:} \textsc{codacond}: Assign a violation for each coda consonant with its own place.
      \textsc{align-\textsc{l}(syll}, \textsc{wd}): Assign a violation for each left edge of a syllable that does not coincide with that of the prosodic word.
      \textsc{b}: \textsc{align-\textsc{l}(syll}, \textsc{wd}): (Disfavors doing nothing.)
      \textbf{blocker:} \textsc{*voigem}: Assign a violation for each voiced geminate.
\end{verbatim}

Note that \textit{Nippon}, ‘Japan’, literally translates into “sun’s origin”. \textit{niti} ‘sun’, at least when combined with the roots above, means ‘Japan’.
CODACOND and ALIGN-L drive root fusion (72), while *VoIGEM >> ALIGN-L blocks it when it would result in a voiced geminate (73).

<table>
<thead>
<tr>
<th>Driver</th>
<th>Blocker</th>
<th>*B</th>
</tr>
</thead>
<tbody>
<tr>
<td>/tu-k/</td>
<td>CODACOND</td>
<td>*VoIGEM</td>
</tr>
<tr>
<td>(72) a.</td>
<td>tu-k</td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>tk</td>
<td></td>
</tr>
<tr>
<td>c. ☞</td>
<td>kk</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Driver</th>
<th>Blocker</th>
<th>*B</th>
</tr>
</thead>
<tbody>
<tr>
<td>/tu-g/</td>
<td>CODACOND</td>
<td>*VoIGEM</td>
</tr>
<tr>
<td>(73) a.</td>
<td>☞ tug</td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>tg</td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td>gg</td>
<td></td>
</tr>
</tbody>
</table>

For root fusion to apply at all in HS, CODACOND (Driver) must be demoted below ALIGN-L (*B) (74). But then syncope will always apply, even where it would later yield a voiced geminate (75). *VoIGEM plays no role, and cannot see if root fusion would produce a voiced geminate.

<table>
<thead>
<tr>
<th>Blocker</th>
<th>*B</th>
<th>Driver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step</td>
<td>/tu-k/</td>
<td>*VoIGEM</td>
</tr>
<tr>
<td>(74) a.</td>
<td>1</td>
<td>tuk</td>
</tr>
<tr>
<td>b.</td>
<td>1</td>
<td>☞ tk</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Blocker</th>
<th>*B</th>
<th>Driver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step</td>
<td>/tu-g/</td>
<td>*VoIGEM</td>
</tr>
<tr>
<td>(75) a.</td>
<td>1</td>
<td>☜ tug</td>
</tr>
<tr>
<td>b.</td>
<td>1</td>
<td>☜ tg</td>
</tr>
</tbody>
</table>

In light of the failed derivation in HS, one could argue that the roots are underlyingly /CVC/ and the root-final vowel is epenthized to avoid C# and voiced geminates in compounds (similar to Lithuanian). Because the derivation could determine if assimilation would yield a voiced geminate in the first step of the derivation, the epenthesis analysis would allow for a successful derivation in HS. Though early work on root fusion posited epenthesis (Ito 1986, Tateishi 1989, Ito & Mester 1996), more recent research has cast doubt on this possibility (Kurisu 2000, Labrune 2012, Ito & Mester 2015, building on Vance 1987): the quality of the final vowel is not predictable in a class of cases, and final vowels can generally carry accent, which is unusual for epenthetic segments. Regardless of these facts, Kurisu (2000) notes that Richness of the Base (Prince & Smolensky 1994/2004) renders the debate meaningless: the facts can be adequately captured without having
to commit to one of the underlying forms, so long as the analysis maps both /CVC/ and /CVCV/ forms to appropriate outputs. We hold HS to this analytical standard, considering prior HS research has relied on Richness of the Base to overcome HS-specific problems in accounting for lexical tone association (McCarthy et al. 2012). HS must supply a way to appropriately condition root fusion in /CVC₁V-C₂VCV/.

5.3 Additional Cases

Stanton (2016) addresses the difficulty of deriving Gurindji nasal spreading in HS. In Gurindji (McConvell 1988), nasal spreads backwards from an NC cluster (ex. /kajira-mpal/ → [kājɪrə-mpal] ‘across the north’), except where [nasal] spreading would result in a NCṼ cluster. In such cases, the [nasal] trigger is deleted instead. (/kankula-mpa/ → [kānkula-pa], [*kānkũlãmpa] ‘on the high ground’). This pattern is a comparison of procedures: either spread [nasal] across an unbounded number of segments, or delete the nasal trigger. The choice between the two procedures comes from whether *NCṼ is violated. In Parallel OT, because the result of spreading through multiple segments takes place in a single step, it will be blocked wherever it would yield a NCṼ cluster. In HS, however, spreading is an iterative, multistep procedure (McCarthy 2011, Kimper 2011a), and so the NCṼ cluster will not be visible in the derivation until [nasal] has already begun spreading, and cannot be undone.

Finally, Anderson (2016) compares Parallel OT and HS with regard to how well they can capture the distribution of footing, metathesis, and syncope in Maltese. Maltese demands right-aligned, disyllabic trochaic feet, with a heavy stressed syllable. In our terms, well-formed feet are built by comparing procedures: syncope generally occurs following footing to satisfy the aforementioned conditions on feet (/li-bdl-u/ → (’ji-b,dl)-u → (’ji-b,dl-u), “they change”), but where syncope would result in a sonority reversal, CV-metathesis occurs as the next best option for satisfying these constraints (/li-f rb-u/ → ji-f rb-u → ji-(’frb-u), /ji-f rb-u/ → *(’frb-u), ‘they drink’). Anderson finds that this is naturally expressed in Parallel OT, wherein the results of the two procedures can be compared, but not in HS, which cannot look ahead to the full result of footing and syncope.

6. Conclusion

Parallel OT and HS differ, among other ways, in that the former can look ahead to the application of entire series of changes, while the latter cannot. The two frameworks make different empirical predictions, and these predictions have significant ramifications. As stated in the introduction, the question of whether the grammar has lookahead has important implications for theories of phonological architecture (Prince & Smolensky 1993/2004; McCarthy 2010a, McCarthy & Pater 2016), learnability (Smolensky 1996, Prince & Tesar 2004, Tessier & Jesney 2014), and computational complexity (Heinz 2011, Heinz & Lai 2013, Bjorkman & Dunbar 2016, Jardine 2016, Heinz to appear; cf. Johnson 1972, Kaplan & Kay 1994).

This paper has argued that lookahead is part of the phonological grammar. We demonstrated that a variety of systems across languages, involving a diverse array of processes, require lookahead. The wide breadth of cases from Mohawk, Maragoli, Lithuanian, Sino-Japanese, Gurindji, and Maltese can be derived in Parallel OT, which has full lookahead, but are recalcitrant for HS, which has no lookahead. Though it might be possible to imagine apparent HS reanalyses
of our cases, those that have been posited previously and novel ones considered here either fail to capture the full set of data or miss important generalizations within and across languages.

Our cases share the same abstract structure, each involving a comparison of procedures: apply one change followed by another unless the full result is dispreferred; in such a case, apply a different series of changes. We have shown that comparisons of procedures in the abstract can be captured in Parallel OT but not HS, which gives a unified explanation for why our cases are challenging for only the latter. We conclude that the diversity of comparisons of procedures found across languages presents a strong argument for the broader necessity of lookahead, and thus for irreducible parallelism.

This is not to say that arguments for serialism do not exist. As pointed out previously, Parallel OT generates a variety of patterns previously claimed to be unattested, while HS avoids them (Wilson 2001, McCarthy 2007, Pruitt 2010, Jesney 2011). Perhaps we need a less restrictive theory that combines serial application with lookahead capability (e.g., Optimality Theory with Candidate Chains; McCarthy 2006, 2007b; Wolf 2008, 2011; a.o.). Nevertheless, the viability of constraint-based serialism not indexed to morphosyntactic strata remains an open question. Apparently unattested grammatical patterns that HS is claimed to correctly exclude could always turn out to exist (cf. Becker & Jurgec 2016). Strong evidence for serialism would consist of attested, productive phonological systems that require reference to intermediate forms. McCarthy (2008) surveys a variety of apparently extant stress-syncope interactions and finds that they challenge Parallel OT but can be treated in HS. Nevertheless, recent research casts doubt on the productivity of stress-syncope interactions, and suggests that learners are unable to actually acquire them (Bowers 2012). Thus, more cases should be accumulated before assessing whether combining lookahead with constraint-based serialism is warranted.

Appendix

7. Evidence for the moraic trochee in Mohawk

In this section, we show that additional interactions between epenthesis, stress, lengthening, and subminimal word augmentation in Mohawk display a broad conspiracy toward foot binarity in the language. Thus, they lend independent support for the analysis given in Section 2. And, we show that, because they do not appeal to the bimoraic foot in understanding Mohawk stress, Elfner (2016)’s HS account and Alderete (1999)’s HEADDEP account fail to capture the full range of data from the language and misses the foot binarity generalization.

7.1 [a]-epenthesis

In addition to the phonologically conditioned process of [e]-insertion, Mohawk also has a morphologically conditioned process of [a]-epenthesis (Michelson 1988, 1989). [a] is inserted at the noun-verb boundary in noun incorporation (76), and at the boundary between a verb and a derivational suffix modifying the verb (77).26

26 Michelson (1988) and Mithun (2009) interpret [a] as morphologically conditioned epenthesis — a joiner vowel, inserted to join two members of a verbal compound. Ralli (2013, pg. 70) compares the Mohawk joiner vowel to a similar vowel found in compounds in Modern Greek, and Zymet (2017) proposes a case of dissimilation marking a suffix boundary.
(76) [a]-insertion: noun incorporation

a. /wak-nuhs=ya-Ø/ [wak.'nuh.s,ya.] 1P-house-own-STAT 158
c. /te-hs-a?ar=rrik-Ø/ [teh.sa.'?a:.rika] DU-2A-curtain-put together-IMP *48

(77) [a]-insertion: verb derivation

a. /k-r=kw-as/ [kg.'rak.was] 1A-fill in-UNDO-HAB 158

Evidence that [a] must be epenthetic, rather than underlying, is that [a] patterns like an epenthetic vowel, not underlying [a], with respect to stress (78 vs. 79). Like for [e] versus [e], Michelson states that [a] are phonetically identical [a] (Michelson 1988, pg. 132).

(78) Underlying [a]: no stress alternation

a. /k-o-har-ha?/ [ko.'har.ha?] 1A-attach-HAB 53
b. /yo-rist-a?natak-u/ [o.ris.ta.?nta:.'ku] NP-iron-stick-STAT 164

(79) Epenthetic [a]: stress alternation

a. /ka-kuw=r-a?/ [ka.'ku.war?] NA-mask, face-in-NSF 164
b. /ka-at-nuw=ya-s/ [ka.te.'nuw.ya.s] 1A-SRF-muddy.water-put-HAB 158

Crucially, [a]-epenthesis behaves almost exactly like [e]-epenthesis: if [a] occupies a closed penult, the penult is stressed (80). If [a] occupies an open penult, the antepenult is stressed (81). Unlike [e]-epenthesis, though, if [a] occupies an open penult, tonic vowel lengthening occurs (compare [ka.te.'nuw.ya.s] versus [te.ka.riks]).

(80) [a] in closed penult: penult stress

b. /k-r=kw-as/ [kg.'rak.was] 1A-fill in-UNDO-HAB 158

(81) [a] in open penult: antepenult stress, tonic vowel lengthening

a. /ka-at-nuw=ya-s/ [ka.te.'nuw.ya.s] 1A-SRF-muddy.water-put-HAB 158
c. /ka-kuw=r-a?/ [ka.'ku.war?] NA-mask, face-in-NSF 164
d. /yo-swahk=r-a?/ [os.'wah.kar?] NP-board-in-NSF 165

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27 We adopt from Michelson (1989) ‘=’ as the gloss of the morpheme boundary where [a] is inserted.
28 /h/ and /y/ (78b) are deleted word-initially (Michelson 1988)
29 Like [e]-epenthesis, if [a] occupies an open penult, and the antepenult is closed, the antepenult simply gets stress, and nothing else occurs (40e).
The analysis of Mohawk in terms of a comparison of foot building procedures naturally extends to the interaction between [a]-epenthesis and stress, and the asymmetry between [a]-epenthesis and [e]-epenthesis with respect to lengthening. A coda consonant allows for a penult (ˈH) when [a] occupies a closed penult (82b). Like for [e]-epenthesis, though, a constraint against long epenthetic vowels blocks the option of a penultimate (ˈH) foot when [a] occupies an open penult (e.g. *[ka.ku(ˈwɑː)ra?]). Where for [e]-epenthesis though, (ˈLL) was built instead (82c), in [a]-epenthesis, an independent constraint against high-sonority vowels in the non-head position of a foot prefers an antepenult (ˈH) instead (82d; e.g. *[ka(ˈkʊwɑː)ra?]).

(82) **Mohawk foot structures: [e]- versus [a]-epenthesis**

<table>
<thead>
<tr>
<th>Closed Penult</th>
<th>Open Penult</th>
</tr>
</thead>
<tbody>
<tr>
<td>[e]</td>
<td></td>
</tr>
<tr>
<td>a. /CVCCCV/</td>
<td>[CV(ˈC_eC)CV]</td>
</tr>
<tr>
<td>/wak-nyak-s/</td>
<td>[wa.ˈken.yaks]</td>
</tr>
<tr>
<td>[a]</td>
<td></td>
</tr>
<tr>
<td>b. /CV=CCV/</td>
<td>[CV(ˈC_aC)CV]</td>
</tr>
</tbody>
</table>

We need an additional constraint to express this analysis. *Non-HD_v/a*, simplified from de Lacy 2006, encodes the preference for low sonority segments in the non-head position of a foot (83). In many languages, high sonority segments like [a] are dispreferred in the non-head position of a foot, while low sonority segments like [e] are permitted (Zec 1995, Kenstowicz 1997, and de Lacy 2006, among others).

(83) **Non-HD_v/a** Assign a violation for a low vowel occupying the nucleus of the non-head syllable of a foot.

The emergence of antepenult (ˈH) when [a] occupies an open penult is due to three additional rankings: DEpV: >> ALIGNR\(^{30}\) prefers a less right-aligned foot over a long epenthetic vowel (84a-b). FtBin >> ALIGNR prefers a less right-aligned foot over (ˈL). And, most interestingly, *Non-HD_v/a >> ALIGNR* prefers a less right-aligned foot over leaving [a] in the non-head position of a foot (84a-d). Note that *Non-HD_v/a must make the decision between (84a) and (84d), not FtHdr, because ALIGNR must rank above FtHdr to derive the choice of (ˈLL) over antepenult (ˈH) when [e] occupies an open penult (85).

<table>
<thead>
<tr>
<th></th>
<th>/CV=CCV/</th>
<th>FtBin</th>
<th>*Non-HD_v/a</th>
<th>DEpV</th>
<th>ALIGNR</th>
<th>FtHdr</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>ˈ(CV:)C_a.CV</td>
<td></td>
<td></td>
<td>**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>CV(ˈCA)CV</td>
<td>*!</td>
<td></td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>c</td>
<td>CV(ˈC_a)CV</td>
<td>!</td>
<td></td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>d</td>
<td>(ˈCV.C_a)CV</td>
<td>*!</td>
<td></td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>e</td>
<td>(ˈCV)C_a.CV</td>
<td>!</td>
<td></td>
<td></td>
<td>**</td>
<td></td>
</tr>
</tbody>
</table>

\(^{30}\) Closed penult forms with [a] are derived in the same way that forms with an underlying penult vowel or [e] in a closed penult are in our analysis (see Section 2).
In sum, the Mohawk analysis in terms of the choice between (‘H) and (‘LL) naturally extends to [a]-epentheses by incorporating a standard constraint on the sonority of non-heads of feet. Facts about multiple epenthesis in the language further corroborate this extension.

7.2 Multiple epenthesis

Patterns of multiple epenthesis, in which epenthetic vowels occupy both the penult and antepenult, further corroborate the role of sonority in Mohawk stress, as well as demonstrate the necessity of ensuring bimoraic feet.

In Mohawk, when [a] occupies an open antepenult and [e] an open penult, the antepenult receives stress, and no lengthening occurs (86). But, when [e] or [a] occupies an open antepenult, and [a] an open penult, the penult receives stress, and [a] gets lengthened (87).

(86) [e] in penult, [a], in antepenult: Antepenultimate stress

<table>
<thead>
<tr>
<th></th>
<th>FtBIN</th>
<th>*Non-HD_{η}/a</th>
<th>DEP:</th>
<th>ALIGNR</th>
<th>FTfHdR</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>(‘CV.Cg.CV)CV</td>
<td></td>
<td></td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>b.</td>
<td>(‘CV:Cg.CV)CV</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(87) [a] in penult, [e] or [a] in antepenult: Penultimate stress

<table>
<thead>
<tr>
<th></th>
<th>FtBIN</th>
<th>*Non-HD_{η}/a</th>
<th>DEP:</th>
<th>ALIGNR</th>
<th>FTfHdR</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>/te-kaʔ-nuksr=ke-O/</td>
<td>[te.kaʔ.nuk.se.‘ra.ke]</td>
<td>DU-NA-onion-be many-STAT</td>
<td>162</td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>/hs-at-wuyh=r=r=r-/</td>
<td>[sa.te.we.yuh.kg.‘ra:ra]</td>
<td>2A-SRF-thumb=in-fill in-IMP</td>
<td>162</td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td>/s-ka-nuyt=r=ti/</td>
<td>[ska.nya.ta.‘ra:ti]</td>
<td>ITER-NA-lake-be one side</td>
<td>65</td>
<td></td>
</tr>
</tbody>
</table>

These facts fall out naturally under the account developed thus far. When [e] occupies an open penult, the familiar pressure against long epenthetic vowels favors (‘LL) (88). However, the constraint against sonorous foot non-heads blocks such an option if [a] occupies the penult. (*([‘Ce.‘ra.CV]) (89). We saw above in (84) that an antepenult (‘H) emerges if [a] occupies an open penult and the antepenultimate vowel is underlying. However, if [e] or [a] occupies an open antepenult as well, an antepenult (‘H) would result in a long epenthetic vowel (*([‘Ce:ra.CV]). Thus, it is impossible to satisfy FtBIN without violating either the constraint against sonorous vowels in the non-head position of a foot, or the constraint against long epenthetic vowels. The former turns out to trump the latter, and since lengthening either the antepenult or the penult will produce a long epenthetic vowel, the general preference for right-aligned feet emerge, and we get a penult (‘H). The formal expression of this analysis is as follows. The ranking we have already established chooses an (‘LL) foot when [e] occupies an open penult, and [a] the antepenult (88). Crucially, the winner does not violate *Non-HD_{η}/a.
When \([a]\) occupies an open penult though, \(*\text{NON-HD}_a^*\text{a} > \text{DEPV}_*\), \text{ALIGNR} blocks the option of an ('LL) foot (89b). And, \text{FtBIN} > \text{DEPV}_*: blocks the option of leaving a foot monomoraic (89d-e). Thus, a violation of \text{DEPV}_*\, is forced, even though the constraint is highly ranked. Since \text{DEPV}_*\, has to be violated, \text{ALIGNR} > \text{ALIGNL} favors a candidate with a more right-aligned foot, all else being equal (89a~c).\(^{31}\)

### 7.3 Subminimal word augmentation

In Mohawk, an interesting set of processes occur when the underlying form only contains a single vowel. These patterns of subminimal word augmentation (Michelson 1988, 1989) perfectly conform to what we expect given the moraic trochee analysis of Mohawk developed thus far: the minimal word in Mohawk is the bimoraic foot plus an extrametrical syllable.

When the underlying form has less than two vowels, \([i]\) is generally inserted at the left edge. If this leaves \([i]\) in a closed penult, nothing else occurs (90). When the underlying form has a CCC or Cr cluster, though, \([e]\) is inserted instead, dually satisfying the need for a sufficiently large word, and constraints against complex consonant clusters and bad syllable contact. If this places \([e]\) in a closed penult nothing else occurs (91). The interesting pattern emerges, though, when \([i]\) or \([e]\) occupy an open penult. If \([i]\) occupies an open penult, it gets lengthened (92). And, when \([e]\) occupies an open penult, \([i]\) gets inserted at the left-edge as well (93). Thus, while a

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\(^{31}\) Assume a candidate with preantepenult stress (e.g. \([('CV)C_{a:.C}V]\)) moves stress too far from the right edge. Kager (2012) finds that no languages with right-aligned bounded stress move stress past the antepenult.
number of processes occur in subminimal word augmentation, a single generalization emerges: a word must contain a bimoraic foot, plus an extrametrical syllable.

(90) [i] into closed penult: Nothing else occurs
a. /k-ya-s/ [ˈik.yas] 1SG.AGT-put-HAB 158
b. /k-yaʔks/ [ˈik.yaʔks] 1A-cut-HAB 163
c. /k-ket-s/ [ˈik.kets] 1A-scrape-HAB *45

(91) [e] into closed penult: Nothing else occurs
a. /k-r-haʔ/ [ˈkgr.haʔ] 1A-fill in-HAB 158
b. /k-rho-s/ [ˈkgr.hos] 1A-coat, spread-HAB 137
c. /s-rho-s/ [ˈsgr.hos] 2A=coat, something-HAB *42

(92) [i] into open penult: Long epenthetic vowel
a. /hra-eʔs/ [ˈhrə.eʔs] MA-go-HAB 54
b. /w-eʔs/ [ˈwə.eʔs] ZA-walk-HAB 54

c. /k-ketaʔs/ [ˈik.ketaʔs] 1A-tie-HAB 141

The analysis of Mohawk stress in terms of a bimoraic foot modulo extrametricality naturally explains the patterns of subminimal word augmentation. Inserting [i] or [e] into a closed penult guarantees a bimoraic foot, (‘H) and extrametrical syllable (90, 91). If [i] or [e] occupy an open penult though, additional processes must occur to meet such a template, otherwise an (‘L) foot would emerge (e.g. *[ˈi]CVC), or the last foot would be footed (e.g. *[(ˈi)CVC]). Thus, additional processes occur to ensure a bimoraic foot.

When [i] occupies an open penult, another [i] cannot be inserted, because that would violate the ban on hiatus (e.g. *(ˈi,i)CV). Thus, we get a long epenthetic vowel as a last resort to ensure a bimoraic foot (92). When [e] occupies an open penult though, [i] can be inserted without creating a hiatus context. Thus, we get an (‘LL) foot (93). In this way, subminimal word augmentation provides strong independent evidence for the primacy of the bimoraic foot in Mohawk. If we just analyzed the Mohawk minimal word as a disyllable, it would be difficult to understand why lengthening occurs in (92), and, why it does not occur in (93).

The formal expression of subminimal word augmentation requires reference to *VV, which expresses the ban on vowel hiatus in Mohawk (94),

32 Vowels are deleted in hiatus contexts (Michelson 1988.).
33 The final vowel is inserted post-lexically (see next sub-section). Thus, it does not count for the sake of building a sufficiently large word.
34 ONSET may also be able to capture the ban on hiatus in Mohawk. In Mohawk, initial syllables can remain onsetless in Mohawk (e.g. [a,ka,ti.’ruː:taʔ] ‘I’ll pull’). Otherwise, vowel deletion ensures word-medial syllables always have onsets (/hra-ukwe/ [ˈhrə:ukwe] man). Consonant insertion never occurs. Thus, a ranking like DepC >> Onset >> MaxV may account for the ban on hiatus, while still correctly deriving the fact that initial syllables remain onsetless.
to ensure that a word is minimal a bimoraic foot plus an extrametrical syllable. \textsc{depv}, assumed to be ranked below constraints compelling \([e]\) and \([a]\) insertion, is violated to ensure a bimoraic foot.

\begin{equation}
\begin{array}{c}
(94) \quad \text{*VV} \quad \text{Assign a violation for every pair of adjacent vowels.}
\end{array}
\end{equation}

\textsc{nonfin} >> \textsc{alignr}, \textsc{depv} compels insertion to ensure an unfooted final syllable (95).\textsuperscript{35}

<table>
<thead>
<tr>
<th>/CCVC/</th>
<th>\textsc{ftbin}</th>
<th>\textsc{nonfin}</th>
<th>\textsc{depv}</th>
<th>\textsc{alignr}</th>
<th>\textsc{depv}</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\emptyset)</td>
<td>((i)C)CVC</td>
<td></td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>((CCVC))</td>
<td></td>
<td>*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Because \([e]\)-insertion into a CCC cluster already guarantees an (\(H\)) foot plus extrametrical syllable, no insertion occurs when \([e]\) occupies a closed penult. Either a violation of \textsc{ftbin} or the gratuitous violation of \textsc{depv} disfavors footing [i] with [e] in a closed penult (96b), and either \textsc{depv}, or gratuitous violations of \textsc{alignr} and \textsc{depv} disfavor a long epenthetic vowel (96c).

<table>
<thead>
<tr>
<th>/CCCVC/</th>
<th>\textsc{ftbin}</th>
<th>\textsc{depv}</th>
<th>\textsc{alignr}</th>
<th>\textsc{fthdr}</th>
<th>\textsc{depv}</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\emptyset)</td>
<td>((i)CeC)CVC</td>
<td></td>
<td>*</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>b.</td>
<td>((i)CeC)CVC</td>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>c.</td>
<td>((i)iCe.C.CVC</td>
<td></td>
<td>*</td>
<td>*</td>
<td>**</td>
</tr>
</tbody>
</table>

However, when [i] or [e] occupy open penults, additional processes must occur to satisfy \textsc{ftbin} and \textsc{nonfin}. If [i] occupies an open penult, \textsc{nonfin} >> \textsc{depv}, \textsc{alignr}, \textsc{depv} prefers a long epenthetic vowel over footing the final syllable (97a-b). \textsc{ftbin} >> \textsc{depv}: prefers a bimoraic foot, even at the expense of an otherwise avoided structure, a long epenthetic vowel (97a-c). Finally, \textsc{*vv} >> \textsc{depv}: prefers a long epenthetic vowel over creating a hiatus (97a-d).

<table>
<thead>
<tr>
<th>/CVC/</th>
<th>\textsc{ftbin}</th>
<th>\textsc{nonfin}</th>
<th>\textsc{*vv}</th>
<th>\textsc{depv}</th>
<th>\textsc{alignr}</th>
<th>\textsc{fthdr}</th>
<th>\textsc{depv}</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\emptyset)</td>
<td>((i):CVC</td>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>((CVC))</td>
<td></td>
<td>*</td>
<td></td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td>((i):CVC)</td>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d.</td>
<td>((i):iCVC)</td>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>**</td>
<td></td>
</tr>
</tbody>
</table>

If [e] occupies an open syllable, [i] is free to be inserted without violating \textsc{*vv}. \textsc{ftbin} >> \textsc{fthdr}, \textsc{depv} motivates insertion to ensure a bimoraic foot. More interestingly, \textsc{depv}: >> \textsc{depv} prefers [i] insertion over epenthesizing a long epenthetic vowel. That is, where in (97) a long epenthetic

\textsuperscript{35} Assume a constraint like \textsc{contig} (McCarthy and Prince 1993a) accounts for the leftward location of [i]-insertion, and that such a constraint is ranked below constraints like \textsc{*complex} and \textsc{syllcon}, which compel insertion into word-medial consonant clusters.
vowel emerged to satisfy FtBIN, in (98), we see that, when possible, inserting another vowel is preferred over violating DepV: 36

<table>
<thead>
<tr>
<th>/CrVC/</th>
<th>FtBIN</th>
<th>*VV</th>
<th>DepV:</th>
<th>AlignR</th>
<th>FtHdrR</th>
<th>DepV</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>(ˈi.Ce)rVC</td>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>**</td>
</tr>
<tr>
<td>b</td>
<td>(ˈCe)rVC</td>
<td>!</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c</td>
<td>(ˈCe:2)rVC</td>
<td></td>
<td>!!</td>
<td>*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Lastly, augmentative forms like [(‘se:2)dht] as in (98) vindicate the use of DepV: as the driving force of stress retraction. Prior analyses have used HEADDep, which militates merely against epenthetic vowels occupying the head position of a foot (Alderete 1999), to explain the retraction seen in e.g. (/te-k-rik-s/, [‘te.2ke.2rik’s]). If DepV: were replaced with HEADDep as the driving force of retraction, then we would have no way of explaining why the augmentative form [(‘se:2)dht] would win over [(‘se:2)dht], since both tie on HEADDep and FtBIN. The same can be said for (/k-hnrk-s/ → [(‘ik).hng.2raks], *[ik.(‘hng:2).2raks]) as in (93c): both candidates tie on HEADDep and FtBIN, and yet, stress retracts. Avoidance of long epenthetic vowels explains these cases. See Rawlins (2006) and Elfner (2016) for discussion of other issues with using HEADDep.

### 7.4 Summary, alternative accounts

Independent processes of epenthesis and subminimal word augmentation all point to the need to ensure a bimoraic foot. Different strategies to ensure either (‘H) or (‘LL) emerge given different inputs. More central to the goal of this paper, this demonstrates that Mohawk stress is an instance of a comparison of procedures, in this case of foot building procedures. Before moving on we briefly discuss the alternative HS account of Mohawk put forth by Elfner (2016).

Adopting Michelson’s (1988, 1989) rule-based analysis into HS, Elfner analyzes the variable location of stress in Mohawk as the result of differential timing between epenthetic processes and stress assignment. Displayed in rule-based format, (99) shows how if insertion into a triconsonantal cluster occurs before stress assignment, but insertion into an oral-consonantsonorant sequence after, we get penultimate versus antepenultimate stress.

<table>
<thead>
<tr>
<th>(99)</th>
<th>Underlying Form</th>
<th>/wak-nyaks/</th>
<th>/wak-ras/</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCC-insertion</td>
<td>wa.ken.yaks</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>PenultStress</td>
<td>wa’.ken.yaks</td>
<td>’wak.ras</td>
<td></td>
</tr>
<tr>
<td>Cr-insertion</td>
<td>-</td>
<td>wa.ken.ras</td>
<td></td>
</tr>
</tbody>
</table>

While we do not set to demonstrate the HS derivation here, the important point is that Elfner appeals to the processes motivating [e]-epenthesis, not whether epenthesis leaves [e] in an open or closed penult, to predict the location of stress. While this adequately derives the basic stress alternation in forms like [wa.’ken.yaks] versus forms like [‘wa.ken.ras], her account provides no explanation

36 Note that a ranking like CONTIG >> FtHdrR is necessary to express that, in non-subminimal word contexts, an (‘LL) foot or lengthening of underlying vowels is preferred over epenthesis to guarantee a bimoraic foot.
for the interactions between stress and lengthening. More crucially, it provides no explanation for the stress patterns associated with [a]-epenthesis, which mirror those of [e]-epenthesis. Recall that whenever [a] occupies a closed penult, it receives stress (e.g., /hra-atʌ-yen=rho-s/, [ra.ʌ.ye. nar.hos]), but when [a] occupies an open penult, the antepenult receives stress (e.g. [ka.ʌn:wa.yas].) Since Elfner (2016) does not reference syllable open/closedness in anyway, to account for [a]-epenthesis she would have to posit two arbitrarily different, *post-hoc* processes of [a]-insertion: one that occurs before stress, wherever [a] gets stress, and one that occurs after stress, wherever [a] does not get stress.\(^{37}\) In this way, by not appealing to a comparison of procedures for satisfying FTBIN, Elfner misses the generalization that antepenult stress emerges when an epenthetic vowel occupies an open penult.

One last point is that Mohawk also has a process of [e]-insertion into word final consonant-glottal stop clusters (henceforth C?#-insertion). This process bears the hallmarks of an insertion process that occurs after stress assignment: it correlates with antepenult stress despite occupying the final syllable (100a,b), it pushes stress to the preantepenult if other epenthetic vowel occupy the penult and antepenult (100c,d) (which otherwise is banned), and finally, it does not count for the calculation of the minimal word (68e,f). While it may be possible to derive this behavior in HS, Houghton (2013) argues that this process really is postlexical. Since all other epenthetic processes display uniform behavior with respect to stress, and otherwise, C?#-insertion is exceptional in every form, it is a good candidate for a post-lexical process. In this case, it can be derived in Stratal OT (e.g. Ito and Mester 2001, 2003; Kiparsky 2000, 2008). And most importantly, while HS may be able to derive C?#-insertion, it is still unable to capture the essential role of the bimoraic foot in understand all other interactions between stress, epenthesis, lengthening, and subminimal word augmentation in Mohawk.

\[\begin{align*}
\text{(100) } & \text{C?#-insertion} \\
\text{a. /ʌ-k-arat-ʔ/} & [\text{ˈʌ.kə.ɾət}] & \text{FUT-1A-\text{lay oneself down-PUNC}} & *43 \\
\text{b. /ro-kut-ot-ʔ/} & [\text{ɾo.ɾu.to.ɾe}] & \text{MA-bir} & *43 \\
\text{c. /waʔ-k-wan-rahw-ʔ/} & [\text{waʔ.ɾe.ɾa.ɾa.ɾe}] & \text{FACT-1A-\text{voice-use-PUNT}} & *64 \\
\text{d. /ʌ-k-rahkw-ʔ/} & [\text{ˈʌ.kə.ɾa.ɾe}] & \text{FUT-1A-\text{use as a container-PUNT}} & *65 \\
\text{e. /ɾ-wa-her-ʔ/} & [\text{ɾə.ɾe.ɾe}] & \text{1in-p-\text{want-HAB}} & 140 \\
\text{f. /ɾ-ʌ-k-hkw-ʔ/} & [\text{ɾə.ɾe.ɾe}] & \text{DU-FUT-1A-\text{lift-PUNC}} & 137
\end{align*}\]

\textbf{Works Cited}


\footnote{Michelson (1988) does just this. She assumes a *post-hoc* “preaccent” and a “postaccent” rule of [a]-insertion.}


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