The Interaction of Stress and Syllabification: Serial or Parallel?

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1. The problem

It is a standard assumption in phonology that stress is assigned to syllables. It would seem to be common sense, then, that syllabification precedes stress assignment. But, as we will see, common sense is wrong in this particular case. Based on evidence from Finnish, we will show that syllabification cannot strictly precede stress assignment, but that the two happen in parallel, as in classical Optimality Theory (Prince and Smolensky 1993/2004). This is potentially problematic for theories where stress and syllabification interact serially, such as in Harmonic Serialism (e.g., McCarthy 2008, 2010; Kimper 2011; Pater 2012; Elfner 2016; Elsman 2016).

In Finnish, a sequence of two vowels (/V_1V_2/) can be syllabified in two ways: The vowels may join to become one syllable nucleus, i.e., a diphthong, or they may split to become two separate syllable nuclei. The two options are illustrated in (1). As we will demonstrate, this choice depends on stress.

(1)	(a)	/au/ → [au]	join (one syllable, diphthong)
	(b)	/au/ → [a.u]	split (two syllables)

The problem can be stated as an ordering paradox: Syllabification feeds stress (what would stress be assigned to if not to syllables?), but stress feeds syllabification, in that the choice between syllabifications depends on stress. We start by laying out the empirical generalizations regarding the syllabification of Finnish vowel pairs (Section 2) and by establishing the existence of variation based on data from metrical verse (Section 3). We then derive the generalizations in terms of Partial Order Optimality Theory (Anttila and Cho 1998, Djalali 2013), a close relative of classical Optimality Theory (Section 4), and show how these generalizations are problematic for Harmonic Serialism, in which syllabification and stress interact serially (Section 5). We conclude by summarizing the main results (Section 6).

2. Empirical generalizations

Finnish syllabification is generally straightforward. The following tableau shows how the word /paperi/ 'paper' is syllabified by assuming the two familiar syllable structure constraints ONSET 'assess a violation mark for every syllable with no onset' and *CODA 'assess a violation mark for every syllable with a coda'. Together, these two constraints favor CV syllables. We mark harmonically bounded candidates by graying out the entire row. For the purposes of our analysis, we need to know the basic principles of Finnish word stress: Primary stress is word-initial; secondary stress falls on every other syllable after that, with the exception of the final syllable.

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(2) Syllabification with ONSET and *CODA.

/paperi/ 'paper'	ONSET	*CODA
☞ (a) pá.pe.ri		
(b) *páp.e.ri	1	1

Syllabification becomes more involved with adjacent vowel pairs. These facts can be summarized as three descriptive generalizations (cf. Häkkinen 1978: 26; Karlsson 1982: 89, 137):

(3) Generalization 1: The sequence /V_1V_2/ is syllabified as a diphthong if V_2 is [+high, −round] (/i/), irrespective of stress. E.g., *ái.kai.nen* 'early' (**ái.ka.ì.nen*, **á.i.kài.nen*, **á.i.kà.i.nen*).

We note that Generalization 1 does not hold with the suffix *-isti* '-ist', whose first vowel is always split into a separate syllable; e.g., *á.te.ìs.ti* 'atheist' (**á.teis.ti*), *dá.da.ìs.ti* 'dadaist' (**dá.dais.ti*). We believe this is because the vowel carries a lexically marked stress, i.e., /-ìsti/, and, for this reason, must form a syllable nucleus on its own.

(4) Generalization 2: The sequence /V_1V_2/ is split into two syllables if V_2 is [−high] (/a, ä, o, ö, e/). E.g., *má.ke.a* 'sweet' (**má.kea*); *Lé.a* 'the proper name Leah' (**Léa*); *sól.mi.o* 'tie' (**sól.mio*); *kí.os.ki* 'kiosk' (**kíos.ki*); *hí.o.a* 'smoothen-INF' (**hío.a, *hí.oa, *híoa*); *lá.si.en* 'glass-PL-GEN' (**lá.sien*); *pá.pe.rì.en* 'paper-PL-GEN' (**pá.pe.rien*); *tér.ri.è.ri* 'terrier' (**tér.rie.ri*)

This generalization has a systematic exception: The vowel pairs /ie, uo, yö/ are always parsed as diphthongs in syllables that receive primary stress; e.g., *tíe* 'road' (**tí.e*); *túo* 'that' (**tú.o*), *ýö* 'night' (**ý.ö*).

(5) Generalization 3: The sequence /V_1V_2/ where V_2 is [+high, +round] (/u, y/) has two possible syllabifications depending on stress: Under primary stress, we will always have a diphthong; e.g., *háu.ta* 'grave' (**há.u.ta*). Elsewhere, we have free variation; e.g., *rák.ka.ù.den* ~ *rák.kau.den* 'love-GEN', *láu.ka.ùs.ta* ~ *láu.kaus.ta* 'shot-PAR'.[1]

Collectively, these three generalizations suggest that the syllabification of two adjacent vowels /V_1V_2/ depends on two main factors: the quality of V_2 in terms of the features [±high] and [±round] and the location of word stress. The fact that stress needs to be mentioned as a caveat in the first two generalizations and as a condition in the third generalization is a clear indication that stress impacts syllabification. More evidence of the role of stress in syllabification will be presented shortly.

To illustrate how these data require us to go beyond the minimal ONSET and *CODA system, let us consider the free variation in /u, y/-final vowel pairs. Tableau (6) shows how ONSET and *CODA fail to capture the variation *láu.ka.ùs.ta* ~ *láu.kaus.ta* 'shot-PAR'.

(6) The failure of ONSET and *CODA.

/laukaus-ta/ 'shot-PAR'	ONSET	*CODA
☞ (a) láu.ka.ùs.ta	1	1
☞ (b) láu.kaus.ta		1
(c) *lá.u.ka.ùs.ta	2	1
(d) *lá.u.kaus.ta	1	1

All four candidates violate *CODA once. Selection falls upon ONSET, which favors diphthongs. As a consequence, ONSET incorrectly rules out variant (a) *láu.ka.ùs.ta*, where /au/ is split into separate syllables. Not only does (a) lose, but it is harmonically bounded, showing that more constraints are needed if we want (a) to win.

[1] According to Kolehmainen (2003), this variable pattern is already mentioned by the late 19th century grammarian Arvid Genetz, suggesting that it has been a stable part of the language for some time.

What might those constraints be? Our three descriptive generalizations suggest that they have something to do with stress and vowel quality. In addition, the fine-grained structure of the variation provides interesting clues as to the identity of these constraints. In an experimental study of the syllabification practices of Finnish high school students, Häkkinen (1978: 26) pointed out that splitting is preferred in closed syllables (i.e., when V_2 is followed by a coda consonant), whereas diphthongs are preferred in open syllables. This pattern is illustrated in (7).

(7) Häkkinen's generalization. Preferred variants are enclosed in boxes.

	OPEN	CLOSED
JOIN	[rák.kau.den]	láu.kaus.ta
SPLIT	rák.ka.ù.den	[láu.ka.ùs.ta]
	'love-GEN'	'shot-PAR'

We propose that Häkkinen's generalization reflects the well-known tendency to avoid stressed light syllables and unstressed heavy syllables (for cross-linguistic evidence, see Hayes 1995). Diphthongs are preferred in open syllables because splitting creates a stressed light syllable (*rák.k**a.ù**.den*). In contrast, splitting is preferred in closed syllables because a diphthong would lead to an unstressed superheavy syllable (*láu.k**aus**.ta*). These preferences translate into frequency differences: Both variants are attested, but diphthongs are more common in open syllables and splitting in closed syllables. Crucially, syllabification is impacted not only by primary stress, but also by secondary stress. While primary stress results in categorical effects, with some syllabifications ruled out completely, secondary stress results in weaker effects that emerge as preferences.

In sum, Finnish vowel pairs can be syllabified in three different ways: They can join to form a diphthong ($/V_1V_2/ \rightarrow V_1V_2$), split into two syllables ($/V_1V_2/ \rightarrow V_1.V_2$), or vary between the two options ($/VV/ \rightarrow V_1V_2 \sim V_1.V_2$). This choice depends on word stress, syllable weight, and vowel quality.

3. Evidence from metrical verse

In order to verify that this variation is real and to test Häkkinen's generalization, we conducted a preliminary study of the syllabification practices of two early 20th century Finnish poets who wrote in syllable-counting meters. We chose two collections of poetry available from Project Gutenberg (gutenberg.org): Juhani Siljo's *Runoja* (1910) and Veikko Antero Koskenniemi's *Elegioja* (1917). All in all, these two works contain 522 /u, y/-final vowel pairs that are not part of a longer vowel sequence (e.g., /VVV/). In 481 of these vowel pairs (92% of all pairs), we found the syllabification unambiguously identifiable: Based on stress and meter, we were able to determine whether the vowels split or join. 426 of these identifiable pairs appear word-initially, i.e., under primary stress, and always form a diphthong, with no possibility of variation. This leaves 55 identifiable syllabifications that do not appear word-initially, i.e., that do not receive primary stress, and are thus potentially variable. These 55 vowel pairs constitute the core data in our preliminary study.

We illustrate our method by examining one line of Koskenniemi's quantitative hexameter. The metrical constraints we used to establish the syllabification are stated by Leino (2002: 163) as follows: (i) a line-final weak position is monosyllabic; (ii) the weak position before the last strong position is disyllabic; and (iii) all other weak positions may have one or two syllables.

(8) (s w) (s w) (s w) (s w) (s w) (s w)
míss' óvat víis**au**s, vóima ja lémp**ey**s, óik**eu**s ýhtä (Koskenniemi)
'where wisdom, strength, gentleness, and justice are one'

This line contains three potentially relevant vowel pairs, emboldened above. Based on (ii), we can infer that the penultimate weak position is disyllabic, i.e., we have *óike.us* 'justice'. Based on (iii), we know that all other weak positions may be monosyllabic or disyllabic, so we cannot conclude anything about the vowel pairs in *víisaus* 'wisdom' and *lémpeys* 'gentleness'. Our general method was to first identify the metrical constraints by examining the entire poem, sometimes with the help of earlier studies (in particular, Leino 2002), and to then identify the syllabification of the relevant vowel pairs as best we could. In strict syllabic meters and Koskenniemi's hexameter, the task was usually straightforward. In Siljo's looser meters, weak positions more freely allow one or two unstressed syllables, making syllabification often impossible to identify. We excluded such cases from our counts. The results from Siljo's *Runoja* are summarized in (9).

(9) The syllabification frequencies in Siljo's (1910) *Runoja*. The variants preferred by Häkkinen's generalization are enclosed in boxes.

	OPEN	CLOSED
JOIN	6	0
	á.vau.tuu	rák.kaus
	'open-REFL-3P.SG'	--
SPLIT	0	14
	á.va.ù.tuu	rák.ka.us
	--	love.NOM

To the extent that we can tell, the syllabifications dispreferred by Häkkinen's generalization are completely absent in Siljo's *Runoja*. We found no splitting in open syllables and no diphthongs in closed syllables. This means that Siljo's verse obeys Häkkinen's generalization *categorically*.

In contrast, in Koskenniemi's *Elegioja*, both syllabification variants are attested in both environments. However, not all variants are equally common, as shown in (10). We found fewer instances of splitting in open syllables than in closed syllables and fewer diphthongs in closed syllables than in open syllables (Fisher's exact test, $p = 0.0009$, two-tailed). This shows that Koskenniemi's verse obeys Häkkinen's generalization, not categorically, but *quantitatively*.

(10) The syllabification frequencies in Koskenniemi's (1917) *Elegioja*. The variants preferred by Häkkinen's generalization are enclosed in boxes.

	OPEN	CLOSED
JOIN	8	1
	káik.keu.den	lém.peys
	'universe-GEN'	'gentleness.NOM'
SPLIT	6	20
	kor.ke.ù.tees	vál.ke.us
	'height-ILL-PX.2.SG'	light.NOM

Summarizing, some /V_1V_2/ pairs in Finnish have two variant syllabifications, e.g., *eu* ~ *e.u*. The distribution of these variants may be complementary (Siljo) or quantitatively skewed (Koskenniemi), depending on whether they would appear in an open or closed syllable. In the next section, we will show how these patterns can be derived from stress and weight.

4. Optimality Theory

4.1. The constraints

Finnish has 8 vowel phonemes, /a, ä, o, ö, u, y, i, e/, which yield 64 logically possible vowel pairs. If we exclude long vowels where $V_1 = V_2$, this leaves us with 56 pairs. Vowel harmony further excludes combinations of /a, o, u/ and /ä, ö, y/, leaving 38 pairs (Karlsson 1982: 85). Our task is to identify the phonological constraints that exclude 20 of these combinations as impermissible diphthongs, leaving the 18 attested diphthongs: /ai, au, äi, äy, oi, ou, öi, öy, ui, yi, iu, iy, ei, eu, ey, ie, uo, yö/. Out of the 18 possible diphthongs, 15 end in a high vowel /ai, au, äi, äy, oi, ou, öi, öy, ui, yi, iu, iy, ei, eu, ey/ and 3 end in a mid vowel /ie, uo, yö/. What constraints predict this particular set of diphthongs?

Let us call the two parts of a diphthong NUCLEUS (V_1) and TAIL (V_2). It is clear that Finnish favors falling diphthongs. Any nucleus can freely combine with any high vowel tail within the limits of vowel harmony. In contrast, rising diphthongs are special; they are only possible in stressed syllables and only if they agree with their nucleus in both [±low] and [±round]. Thus, in /ie/, both vowels are [−low] and [−round] and, in /uo/ and /yö/, both vowels are [−low] and [+round]. The three constraints in (11), stated as local conjunctions of simple constraints (Smolensky 1993), express these generalizations. By making these constraints undominated, we can derive the class of 18 possible diphthongs.

(11) Undominated constraints on diphthongs.

- (a) *TAIL([−HIGH]) & *[−STRESS]
  ‘Assign a violation to a diphthong with a [−high] tail in an unstressed syllable.
- (b) *TAIL([−HIGH]) & AGREE([±LOW])
  ‘Assign a violation to a diphthong with a [−high] tail that disagrees in [±low] with the nucleus.
- (c) *TAIL([−HIGH]) & AGREE([±ROUND])
  ‘Assign a violation to a diphthong with a [−high] tail that disagrees in [±round] with the nucleus.’

We can now focus on the vowel pairs that can form diphthongs in Finnish. First, let us consider the effect of vowel quality: If V_2 is /i/, the result is a diphthong, but, if V_2 is /u, y/, the result is variation. This suggests that /u, y/ are higher on the sonority scale than /i/ and make better nuclei. In (12), we state this in terms of a stringency hierarchy of constraints on nuclei.

(12) The nuclear sonority constraints (see, e.g., Kiparsky 1994, de Lacy 2004).

(a)	*NUC/i	‘No high unrounded vowel nuclei’
(b)	*NUC/iuy	‘No high vowel nuclei’
(c)	*NUC/iuyeo	‘No non-low vowel nuclei’
(d)	*NUC/iuyeoa (= *NUC/V)	‘No vocalic nuclei’

These constraints split the sonority scale into four parts. Critically, (a) and (b) guarantee that high unrounded vowel nuclei are penalized more heavily than other high vowel nuclei, allowing us to distinguish between /i/ and /u, y/. In addition, the last constraint (d) is violated by every vocalic nucleus. This has the interesting side effect of minimizing the number of syllables, which in turn favors diphthongs across the board.

Finally, we can derive Häkkinen’s generalization from the constraints in (13).

(13) The stress-weight constraints (Prince 1990, Prince and Smolensky 1993/2004).

(a)	Peak-Prominence (PK-PROM, *Ĺ)	‘No stressed light syllables’
(b)	Weight-to-Stress Principle (WSP, *H)	‘No unstressed heavy syllables’

Diphthongs are preferred in open syllables because splitting creates a stressed light syllable (*rák.k**a**.**ù**.den*). Likewise, splitting is preferred in closed syllables because a diphthong leads to an unstressed superheavy syllable (*láu.k**au**s.ta*).

4.2. Analyzing variation

To account for variation, we adopt Partial Order Optimality Theory, which allows grammars where rankings are not total, but partial (see Anttila 2012 for an overview and references). As an illustrative example, consider tableau (14). No rankings are assumed.

(14) A grammar with no rankings.

Input	C1	C2	C3
(a) Output 1	1		
(b) Output 2		1	1

This grammar is compatible with the six total orders in (15), shown with their respective winners. We also show each winner's RANKING VOLUME (R-VOLUME, Riggle 2010): the proportion of total orders in the grammar that select this winner.

(15)

TOTAL ORDER		WINNER	
C1 >> C2 >> C3	☞	[Output 2]	R-volume(Output 2) = 2/6 = 0.33
C1 >> C3 >> C2	☞	[Output 2]	
C2 >> C1 >> C3	☞	[Output 1]	R-volume(Output 1) = 4/6 = 0.67
C2 >> C3 >> C1	☞	[Output 1]	
C3 >> C1 >> C2	☞	[Output 1]	
C3 >> C2 >> C1	☞	[Output 1]	

By hypothesis, at the moment of performance, a speaker samples a total order from the set of possible total orders (with replacement). This results in a quantitative prediction: Output 1 has a higher probability than Output 2.

Given our six constraints, *láu.ka.ùs.ta* ~ *láu.kaus.ta* and *rák.ka.ù.den* ~ *rák.kau.den* are correctly predicted. The first is shown in (16). Candidates (a) and (b) are the possible winners, but the one that is produced depends on the speaker's selection of a total ranking at the moment of performance. Candidates (c) and (d) are harmonically bounded and thus categorically excluded.

(16) Free variation *láu.ka.ùs.ta* ~ *láu.kaus.ta* 'shot-PAR'.

/laukaus-ta/ 'shot-PAR'	*NUC/i	WSP	*NUC/ iuy	*NUC/ iuyeo	*NUC/ iuyeoa	PK-PROM
☞ (a) láu.ka.ùs.ta			1	1	4	
☞ (b) láu.kaus.ta		1			3	
(c) *lá.u.ka.ùs.ta			2	2	5	1
(d) *lá.u.kaus.ta		1	1	1	4	1

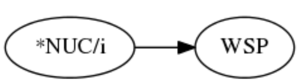
But, what if an input has V_2 = /i/? Such a tableau is shown in (17). The desired winner is (a).[2]

(17) Invariant diphthongs in *ái.kai.nen* 'early'.

/aikainen/ 'early'	*NUC/i	WSP	*NUC/ iuy	*NUC/ iuyeo	*NUC/ iuyeoa	PK-PROM
☞ (a) ái.kai.nen		1		1	3	
(b) *ái.ka.ì.nen	1		1	2	4	1
(c) *á.i.kài.nen	1		1	2	4	1
(d) *á.i.kà.i.nen	2		2	3	5	2

Although (d) is correctly ruled out by harmonic bounding, we still need a ranking that rules out (b) and (c) while guaranteeing that the variable examples continue to be predicted. There are many such rankings available. However, since simpler theories are better, all else being equal, we opt for the *simplest* grammar that *works*. By *simplest*, we mean the grammar with the fewest pairwise constraint rankings. By *works*, we mean a grammar that predicts all and only the attested variants. These two criteria lead to the grammar in (18), which we found with the help of OTOrder (Djalali and Jeffers 2015), a web application for working with Partial Order Optimality Theory.

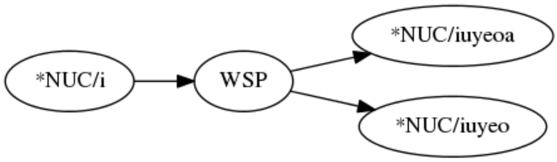
(18) The simplest grammar that works (first iteration).



[2] We assume that word-final consonants are extrametrical; hence, a word-final CVC is actually CV<C>, which counts as a light syllable and does not violate the Weight-to-Stress Principle.

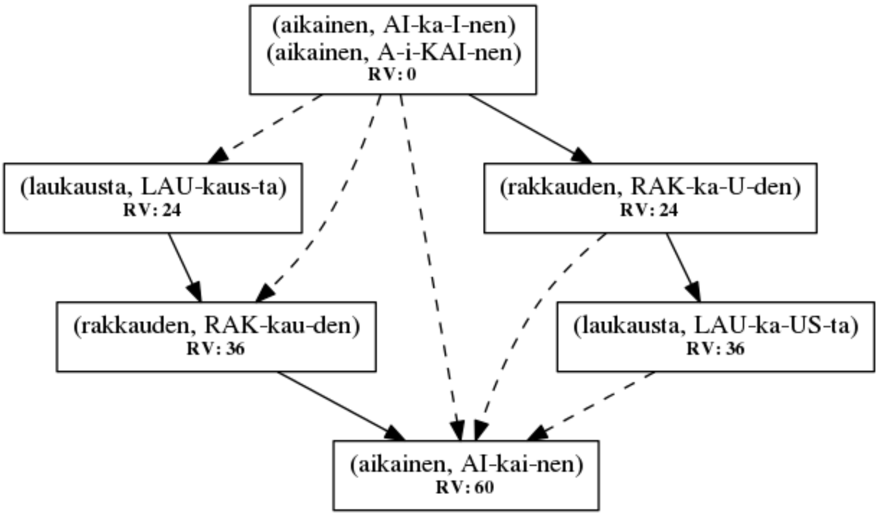
These constraints with the single pairwise ranking *NUC/i » WSP correctly predict the invariant diphthongs in *ái.kai.nen*, as well as the variation in *láu.ka.ùs.ta* ~ *láu.kaus.ta* and *rák.ka.ù.den* ~ *rák.kau.den*. Adding the following examples allows us to infer WSP » {*NUC/iuyeo, *NUC/iuyeoa}: *tíe* 'road', *tíu* 'score', *lá.si.en* 'glass-PL-GEN', *káu.si* 'period', *té.ra.pèut.ti* 'therapist' (no variation); *rák.ka.us* ~ *rák.kaus* 'love', *vá.pau.dès.ta* ~ *vá.pa.u.dès.ta* 'freedom-ELA', *nó.pe.ùt.ti* ~ *nó.peut.ti* 'speed.up-PAST' (variation). The resulting ranking shown in (19) predicts all of the data discussed so far.

(19) The simplest grammar that works (second iteration).



This grammar predicts Häkkinen's generalization: Splitting has a higher probability in closed syllables than in open syllables; the reverse holds for diphthongs. Häkkinen's generalization is visible from the diagram in (20), generated by OTOrder (Djalali and Jeffers 2015). Anttila and Andrus (2006) refer to these diagrams as T-ORDERS. The nodes display syllabifications for three words, /aikainen/, /laukausta/, and /rakkauden/, with ranking volumes (RV) for each syllabification. The ranking volumes range from 0 (never predicted) to 60 (predicted by all total orders). Stressed syllables are capitalized and syllable boundaries are marked with hyphens. Harmonically bounded syllabifications have been omitted.

(20) A T-ORDER diagram that shows Häkkinen's generalization.



To understand the arrows, imagine that each node is the set of total orders that predicts its syllabification as optimal. The arrows denote subset relationships amongst these sets of total orders. For example, the 24 total orders that predict *láu.kaus.ta* (diphthong, closed syllable) are a subset of the 36 total orders that predict *rák.kau.den* (diphthong, open syllable). Similarly, the 24 total orders that predict *rák.ka.ù.den* (split, open syllable) are a subset of the 36 total orders that predict *láu.ka.ùs.ta* (split, closed syllable). Häkkinen's generalization is borne out: There are more grammars that predict a diphthong in an open syllable than in a closed syllable, while the reverse holds for splitting.

Lastly, there are two kinds of arrows. Solid arrows denote universal subset relationships that hold no matter how the constraints are ranked and dashed arrows denote language-specific subset relationships that hold due to some partial ranking in the grammar. We can now see that Häkkinen's generalization is a Greenberg universal.

This analysis makes various general predictions. For instance, it predicts that syllabification is affected by the location of the vowel sequence within the word, as secondary stress is typically limited to odd syllables, affecting syllabification. Consider the minimal pair in (21).

(21) (a) /nope-utta-i/ nó.peut.ti ~ nó.pe.ùt.ti 'speed.up-CAUS-PAST'
(b) /terapeutti/ té.ra.pèut.ti (*té.ra.pe.ùt.ti, *té.ra.pè.ut.ti) 'therapist'

The diphthong parse for /eu/ is optional in the second syllable, but obligatory in the third syllable, where the vowel pair receives secondary stress.

The example in (21) suggests an alternative analysis noted in passing by Karlsson (1982: 89): In variable examples the vowel sequence straddles a morpheme boundary, causing the vowels to split into separate syllables. However, a morpheme boundary does not always make splitting possible. For example, both /ava-us/ 'opening' (open-NOM) and /ava-in/ 'key' (open-INSTR) contain a morpheme boundary, but only the former varies: *á.vaus* ~ *á.va.us* versus *á.vain* (**á.va.in*). Neither does splitting require a morpheme boundary: In /hio-taC/ → *hí.o.a* 'to smoothen' (smoothen-INF), only the second syllable boundary coincides with a morpheme boundary. Finally, morphology provides no explanation for Häkkinen's generalization, which unmistakably points at stress and weight.

5. Harmonic Serialism

Harmonic Serialism (HS) is a theory related to parallel Optimality Theory. The main difference is that HS posits derivations with intermediate steps. Changes are made one at a time, with a re-evaluation at each step, until there is no improvement. For an introduction, see McCarthy (2010). HS takes seriously the observation that some generalizations seem to be intrinsically derivational. For example, in many languages, some or all unstressed vowels delete (McCarthy 2008). This generalization seems derivational: We need to know where stress falls before we can know which vowels to delete. As McCarthy (2008) shows, this generalization is unproblematic in HS.

How would the Finnish puzzle work out in HS? Drawing on McCarthy (2008), Kimper (2011), Pater (2012), Elfner (2016), and Elsman (2016), we outline one possible HS analysis. We start by assuming that syllabification is intrinsically ordered before stress assignment. At the syllabification step, variation is predicted; e.g., *rak.kau.den* (diphthong) ~ *rak.ka.u.den* (split) 'love-GEN' and *rak.kaut.ta* (diphthong) ~ *rak.ka.ut.ta* (split) 'love-PAR'. At this point, the derivation branches and each variant is evaluated independently (cf. Kimper 2011 for analyzing variation in HS). At the stress assignment step, there is no variation and each syllabification is assigned the appropriate stress pattern; here, *rák.ka.ù.den* ~ *rák.kau.den* and *rák.ka.ùt.ta* ~ *rák.kaut.ta*. This correctly derives all of the attested surface forms.

Following Elsman (2016), cited in McCarthy (n.d.), we take the motivation for splitting to be the WSP: Stress is not yet present at the syllabification step, hence, all heavy syllables are unstressed and violate the WSP. This includes all diphthongs.[3] Splitting a heavy syllable into two light syllables is a way to avoid a WSP violation. Since splitting is variable, some constraint must optionally dominate the WSP. In our case, any of the constraints *NUC/iuy, *NUC/iuyeo, *NUC/iuyeoa would do. Tableau (22) predicts variation between the splitting and diphthong candidates in an open syllable.

(22) Predicting variable syllabification in an open syllable.

/rakkauden/ 'love-GEN'	*NUC/i	WSP	*NUC/ iuy	*NUC/ iuyeo	*NUC/ iuyeoa	PK-PROM
☞ (a) rak.ka.u.den		1	1	2	4	
☞ (b) rak.kau.den		2		1	3	

Tableau (23) attempts to predict variation between the splitting and diphthong candidates in a closed syllable. However, it is here that the HS analysis hits a snag.

[3] Finnish has been analyzed as having both light and heavy diphthongs (Keyser and Kiparsky 1984). For example, *oi* can be either light or heavy depending on secondary stress. However, all light diphthongs appear to have a [+high, −round] tail (/i/), which cannot split for independent reasons. Here, we ignore this distinction.

(23) No variation predicted in a closed syllable.

/rakkautta/ 'love-PAR'	*NUC/i	WSP	*NUC/ iuy	*NUC/ iuyeo	*NUC/ iuyeoa	PK-PROM
☞ (a) rak.ka.ut.ta		2	1	2	4	
☞ (b) rak.kaut.ta		2		1	3	

The problem is that splitting cannot avoid a WSP violation in a closed syllable. Both the diphthong parse *rak.kaut.ta* and the split parse *rak.ka.ut.ta* violate the WSP. This has the unfortunate consequence of making the split parse harmonically bounded. Instead of variation, the analysis predicts that splitting is impossible in closed syllables but allowed in open syllables, contra Häkkinen's generalization. The serial analysis thus falls apart at the syllabification step.

Compare this failure to the success of the parallel analysis: Under parallel evaluation, *rák.ka.ùt.ta* is unproblematic because the split parse for /au/ (i.e., *ka.ùt*) does not incur a WSP violation, unlike the diphthong parse. The splitting candidate is rescued by secondary stress. This suggests that secondary stress needs to be present at the point of syllabification, therefore, syllabification cannot be intrinsically ordered before stress assignment.

Related problems emerge in the quantitative domain. Häkkinen's generalization entails that splitting is more likely in closed syllables than in open syllables. Accordingly, we expect the split variant to be more common in *rak.ka.us* ~ *rak.kaus* 'love' than in *rak.ka.u.den* ~ *rak.kau.den* 'love-GEN'. This asymmetry is correctly predicted under the parallel analysis as a Greenberg universal. However, under the HS analysis, the two cases have identical violation profiles, as shown in (24).[4]

(24) The HS syllabification step for /rakkauden/ and /rakkaus/.

/rakkauden/ 'love-GEN'	*NUC/i	WSP	*NUC/ iuy	*NUC/ iuyeo	*NUC/ iuyeoa	PK-PROM
☞ (a) rak.ka.u.den		1	1	2	4	
☞ (b) rak.kau.den		2		1	3	
/rakkaus/ 'love'	*NUC/i	WSP	*NUC/ iuy	*NUC/ iuyeo	*NUC/ iuyeoa	PK-PROM
☞ (a) rak.ka.us		1	1	1	3	
☞ (b) rak.kaus		2			2	

Having identical violation profiles implies grammatical identity in every respect. In quantitative terms, it predicts that the two words should undergo splitting at exactly the same rate, which is incorrect. Note that the parallel analysis correctly predicts the quantitative asymmetry because the secondary stress in *rák.ka.ù.den* incurs a violation of PK-PROM.

The stress assignment step is further unable to derive the relevant quantitative differences. Even though it is too late to revive the split variant *rak.ka.ut.ta* 'love-PAR', we might hope that stress could derive the probabilistic differences among the variants still remaining: *rak.ka.u.den* ~ *rak.kau.den* from (22) and *rak.kaut.ta* from (23). But, as each variant is assigned stress independently (i.e., in its own derivational branch), each variant is predicted to be equally likely: *rák.ka.ù.den* ~ *rák.kau.den* and *rák.kaut.ta*. In particular, both *rák.kau.den* (i.e., a diphthong in an open syllable) and *rák.kaut.ta* (i.e., a diphthong in a closed syllable) win in all of the total orders in their respective branch, erroneously predicting that the two words allow diphthongs at the same rate. In short, once we are past syllabification, it is too late: Stress cannot patch up the analysis and deliver Häkkinen's generalization.

[4] The absolute number of violations differs across the inputs for *NUC/iuyeo and *NUC/iuyeoa, but that is irrelevant because the comparative patterns are the same. Both constraints favor the diphthong candidate (b) over the splitting candidate (a). Recall that word-final consonants are extrametrical; hence, the word-final CVC is interpreted as CV<C>, which counts as a light syllable and does not violate the Weight-to-Stress Principle.

6. Conclusion

Based on evidence from Finnish, we have argued that syllabification cannot strictly precede stress assignment, but that the two must happen in parallel, as expected under classical Optimality Theory. We presented an analysis in terms of Partial Order Optimality Theory that correctly delivers both the invariant and variable syllabifications of adjacent vowel pairs, including a key asymmetry that emerges both categorically and quantitatively (Häkkinen's generalization). We showed that these facts are problematic for Harmonic Serialism (HS), where stress and syllabification interact serially: Syllabification needs stress in order to apply correctly, but HS does not allow it the lookahead it needs. There may well exist an HS analysis that overcomes these problems, but, at the moment, we do not know what it is. We conclude that stress and syllabification interact in parallel, not serially.

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