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Directional Constraint Evaluation Solves the Problem of Ties in Harmonic Serialism

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Abstract: This squib examines the problem of tied candidates in Harmonic Serialism and presents directional constraint evaluation as a solution. Under standard evaluation, constraints report how many loci of violation a candidate contains and, as a result, cannot differentiate two candidates with equal numbers of violations. Under directional evaluation, constraints report where loci of violation occur and are thus able to distinguish candidates with distinct loci of violation. Alternative tie-breaking mechanisms either fail to solve ties in general or introduce unwanted typological predictions.

Keywords: Harmonic Serialism, tied candidates, directional constraint evaluation

1 Introduction

This squib examines the problem of tied candidates in Harmonic Serialism (HS; Prince and Smolensky 1993, McCarthy 2000, 2016) and presents directional constraint evaluation (Eisner 2000, 2002) as a solution. Under standard evaluation, constraints report *how many* loci of violation a candidate contains and, as a result, cannot differentiate two candidates with equal numbers of violations. Under directional evaluation, constraints report *where* loci of violation occur and are thus able to distinguish candidates with distinct loci of violation. Alternative tie-breaking mechanisms either fail to solve ties in general or introduce unwanted typological predictions.

Candidates tie when they cannot be differentiated by Eval. With traditionally evaluated constraints, which count loci of violation, ties occur whenever candidates have the same number of violations. Following Pruitt's (2009) terminology, ties are either convergent or divergent. In a convergent tie, choosing between optima does not affect the ultimate output. The tableau in (1) illustrates this with a derivation mapping /aaaa/ onto [bbbb]; mappings in this squib abstract away from phonological substance because ties are a problem of Eval, not a given representation. The faithful candidate (1a) is dispreferred to the four unfaithful candidates (1b–e), which tie.

This work has greatly benefited from two anonymous reviewers for *LI* and discussions with John McCarthy and Joe Pater. All remaining errors are of course my own.

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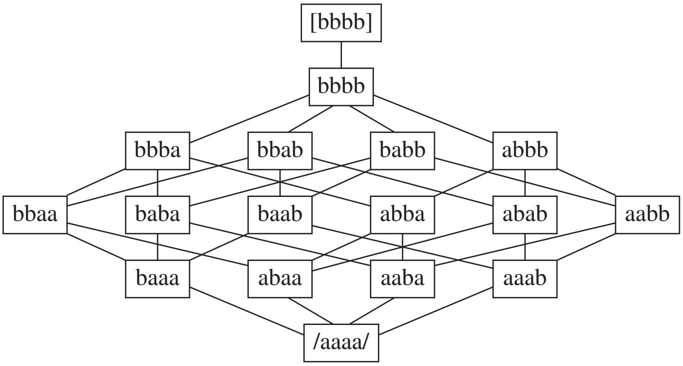
(1) /aaaa/ → [bbbb], Step 1

/aaaa/	*a	IDENT
a. aaaa	W 4	L
→ b. baaa	3	1
→ c. abaa	3	1
→ d. aaba	3	1
→ e. aaab	3	1

In (1), an optimal candidate can be chosen randomly without consequence: regardless of the order in which each /a/ is changed, the derivation converges on [bbbb]. All possible derivations from /aaaa/ to [bbbb] are shown in (2), which represents harmonic improvement vertically. Every path that starts with the underlying representation (UR) /aaaa/ at the bottom, moves upward through a chain of intermediate representations, and ends with the output [bbbb] at the top is a possible derivation.

(2)



In a divergent tie, choosing between tied candidates does affect the ultimate output, creating variation. This is undesirable because there is no way to control the relative frequencies between the tied candidates (see Anttila 2002 for critical discussion of tied candidates as a theory of variation). The tableau in (3) illustrates a divergent tie with assimilation; the markedness constraint penalizes adjacent segments that are not identical. The fully faithful candidate (3a) and the unfaithful candidates where an edge segment was changed (3b,f) are dispreferred to the other unfaithful candidates (3c–e). Because loci of violation overlap, targeting interior segments offers more harmonic improvement than targeting edge segments. Candidates (3c–e) have the same number of violations and tie.

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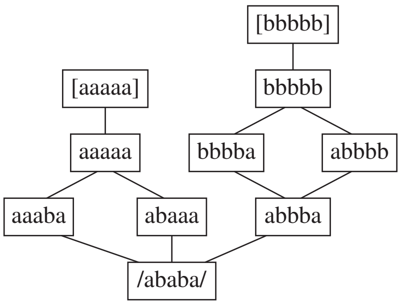
(3) Divergent assimilation, Step 1

/ababa/	*{ab, ba}	IDENT
a. ababa	W 4	L
b. bbaba	W 3	1
→ c. aaaba	2	1
→ d. abbba	2	1
→ e. abaaa	2	1
f. ababb	W 3	1

The derivational paths from this step are represented in (4). If candidates (3c,e) are chosen, the derivation converges on [aaaaa]. If candidate (3d) is chosen instead, the derivation converges on [bbbbb]. While the UR /ababa/ is only mapped onto fully agreeing outputs, the space of possible outputs grows with the length of the UR. For example, the UR /ababababa/ can surface as [aaaaaaaaa], [aaaaabbbb], [aaabbbaaa], [aaabbbbbb], [bbbbaaaaa], [bbbbbbaaa], or [bbbbbbbbb].

(4)



This example demonstrates how ties differ in parallel Optimality Theory (pOT) and HS. Because HS is derivational, ties can occur in intermediate steps, as in (3), and introduce cascading variation. In pOT, [bbbbb] is not a possible output because it is evaluated in parallel along with [aaaaa]. Both candidates satisfy *{ab, ba}, but the latter minimizes the violations of IDENT, exemplifying Majority Rule (Lombardi 1999, Baković 2000; see Lamont 2019 for a discussion of Majority Rule in HS), wherein the relative magnitude of two classes in the input determines the output. In HS, EVAL has no lookahead capability and so cannot disprefer candidate (3d) on the basis of its longer derivation.

The tie in (3) can be broken by including additional constraints. For example, a markedness constraint that penalizes [b] would rule out candidate (3d), as would a faithfulness constraint that penalizes the mapping /a/ → [b]. This would leave candidates (3c,e) as tied op-

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tima, and the derivation would converge on [aaaaa]. McCarthy (2009) dubs cases like (3) "ties of neglect" and argues they are not a deep theoretical problem, but instead reflect an incomplete analysis. He contrasts ties of neglect with "ties of principle," which resist intervention by additional constraints. In HS, ties of principle are characterized by some operation applying at different positions in the input. Two case studies of divergent ties of principle are presented in section 2. Section 3 demonstrates that directional constraint evaluation (Eisner 2000, 2002) eliminates ties, and section 4 discusses alternative tie-breaking mechanisms. Section 5 briefly concludes.

2 The Problem: Divergent Ties of Principle

The tableau in (5) illustrates a divergent tie of principle with dissimilation: the markedness constraint penalizes adjacent segments that are both [a].[1] The fully faithful candidate (5a) and the unfaithful candidates where an edge segment was changed (5b,f) are dispreferred to the unfaithful candidates where an interior segment was changed (5c–e). It is better to target interior segments than edge segments, but there is no way to choose between interior segments. All three tied candidates were derived by mapping an /a/ onto a [b] and are only distinguished by the position at which the mapping occurred. Thus, unlike the assimilation case in (3), these candidates cannot be distinguished by penalizing a specific segment or a specific mapping.

(5) Divergent dissimilation, Step 1

/aaaaa/	*aa	Ident
a. aaaaa	W 4	L
b. baaaa	W 3	1
→ c. abaaa	2	1
→ d. aabaa	2	1
→ e. aaaba	2	1
f. aaaab	W 3	1

The derivational paths from this step are represented in (6). If candidates (5c,e) are chosen as optimal, the derivation converges on [ababa]. If candidate (5d) is chosen instead, the derivation can converge on [babab], [abbab], [babba], or [abbba]. These four outputs would be harmonically bounded in pOT: while all five possible outputs satisfy *aa, [ababa] minimizes the violations of Ident.

[1] All the cases in this squib were verified using the script available at https://github.com/aphonologist/hs-ties.

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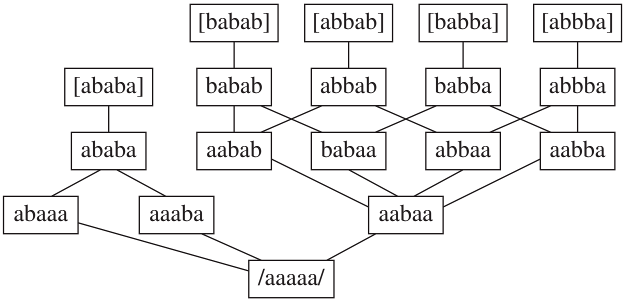
(6)



Another example of a divergent tie of principle is illustrated in the tableau in (7) with epenthesis; the markedness constraint penalizes three adjacent segments that are all [b]. The fully faithful candidate (7a) and the unfaithful candidates where an [a] was inserted close to the edge (7b–c,g–h) are dispreferred to the other unfaithful candidates (7d–f). As in (5), the tied candidates are all derived by the same mapping, which inserts [a], and are differentiated only by where it applies.

(7) Divergent epenthesis, Step 1

/bbbbbb/	*bbb	Dep
a. bbbbbb	W 4	L
b. abbbbbb	W 4	1
c. babbbbb	W 3	1
→ d. bbabbbb	2	1
→ e. bbbabbb	2	1
→ f. bbbbabb	2	1
g. bbbbbab	W 3	1
h. bbbbbba	W 4	1

The derivational paths from this step are represented in (8). If candidates (7d,f) are chosen, the derivation converges on [bbabbabb]. If candidate (7e) is chosen instead, the derivation can converge on [babbabbab], [babbababb], [bbababbab], or [bbabababb]. As above, these four outputs are harmonically bounded in pOT, as they contain three epenthetic vowels and [bbabbabb] contains only two.

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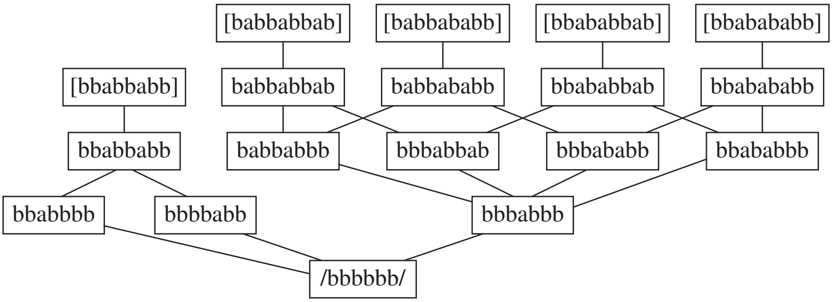
(8)



3 A Solution: Directional Constraint Evaluation

The question of which locus of violation to apply a given operation to echoes the question in rule-based phonological theory of how to apply a rule to an input with multiple foci. Section 2 showed that random choice yields chaotic, unpredictable derivations, and outside of one hypothetical aside (Anderson 1974:221), I am unaware of any proposals in rule-based phonology that advocate random choice. Iterative models that target foci one at a time are typically directional: rules start at one edge of an input and work their way across (Brown 1972, Howard 1972, Johnson 1972, Jensen and Stong-Jensen 1973, Cearley 1974, Vago and Battistella 1982). Imposing directional application on HS is a principled way to break ties.

One way to impose directional application is to adopt directional constraint evaluation (Eisner 2000, 2002, Finley 2008, 2009, Lamont 2019). Under directional evaluation, constraints return a violation tuple, which records the location of loci of violation relative to the input, rather than a single value reporting the total number of loci. Constraints are specified as evaluating left to right (⇒) or right to left (⇐). Like traditional constraints, directional constraints prefer candidates without violations to candidates with violations. Directional constraints further distinguish violations on the basis of their location within candidates: under left-to-right evaluation, constraints prefer loci to be as far to the right as possible, and under right-to-left evaluation, constraints prefer loci to be as far to the left as possible.

Directional evaluation originated as a computational restriction on pOT. Eisner (2000, 2002) demonstrated that if GEN is a regular relation and CON comprises only directional constraints and bounded constraints (i.e., constraints that only count up to a fixed number (Frank and Satta 1998)), pOT only produces regular mappings. Thus, directional evaluation eliminates nonregular mappings such as the Midpoint Pathology (Eisner 1997) and Majority Rule (Lombardi 1999, Baković 2000). Adopting Eisner's restrictions in HS guarantees that each step is a regular mapping, but this does not necessarily imply that entire derivations are regular mappings. However, the nontrivial resemblance of HS with directional constraints to Johnson's (1972) linear rules, which are known to be regular mappings, suggests similar restrictive-

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ness. Directional evaluation is also a general solution to the problem of ties. Ties of principle do not arise because candidates with different loci of violation are distinguished by the positions of their loci.

As an illustration, consider the tableau in (9).

(9) /ababa/ ⟶ [aaaaa], Step 1

/ababa/	$*\{ab, ba\}^{\Rightarrow}$					IDENT
a. ababa	W	a_1b_2	b_2a_3	a_3b_4	b_4a_5	L
b. bbaba	W		b_2a_3	a_3b_4	b_4a_5	1
⟶ c. aaaba				a_3b_4	b_4a_5	1
d. abbba	W	a_1b_2			b_4a_5	1
e. abaaa	W	a_1b_2	b_2a_3			1
f. ababb	W	a_1b_2	b_2a_3	a_3b_4		1

This tableau is the same as the tableau in (3), except that the markedness constraint is evaluated directionally. The markedness constraint *{ab, ba} is evaluated left to right, as the superscript arrow ⇒ indicates. As a result, it imposes a harmonic order on the loci of violation according to their position relative to the input. The leftmost locus [a_1b_2] is strictly worse than its successor [b_2a_3], and so on. For visual clarity, loci are shown in the tableau with indices. Whereas traditional evaluation cannot distinguish candidates with an equal number of loci, directional evaluation imposes a total harmonic order on candidates with different sets of loci. Candidates (9a,d–f) with the worst locus [a_1b_2] are strictly worse than candidates (9b–c). Notice that the total number of violations is irrelevant; candidate (9b) has three violations but is better than candidates (9d–e), which have only two violations. Candidate (9c) is chosen as optimal because candidate (9b) has an additional locus of violation [b_2a_3]. The harmonic ordering on loci determines which locus is targeted at each step. All other things being equal, it is always optimal to target the leftmost/rightmost locus, and candidates cannot tie. Directional evaluation guarantees the leftmost/rightmost locus is targeted, not necessarily the leftmost/rightmost violating segment. Note that left-to-right application is consistent with two theories of CON: one with parameterized constraints and *{ab, ba} is specified as left to right, and one with both directional versions and $*\{ab, ba\}^{\Rightarrow}$ dominates $*\{ab, ba\}^{\Leftarrow}$.

The derivational path from this step is represented in (10). The thick solid line traces the derivation with left-to-right evaluation, and the thick dashed line represents right-to-left evaluation; both derivations converge on [aaaaa]. For the grammar to converge on [bbbbb], the first step would have to target the loci in the center of the input, as in candidate (9d), preserving the leftmost and rightmost loci. Because loci at the edges of the input are strictly worse than those in the center, this is impossible. Both directions of evaluation converge on

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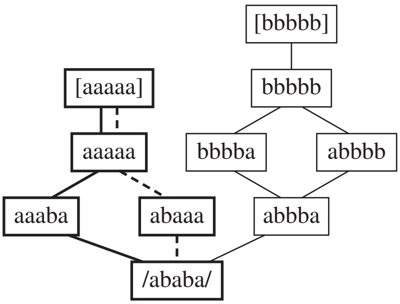
[aaaaa] because the input is a palindrome; it is not true in general that left-to-right evaluation and right-to-left evaluation converge on the same output. For example, with the UR /ababab/, left-to-right evaluation produces the output [aaaaaa], and right-to-left evaluation produces [bbbbbb].

(10)



In the tableau in (9), only the markedness constraint is evaluated directionally; the faithfulness constraint is evaluated traditionally. This reflects a theory of Con wherein all and only markedness constraints are evaluated directionally (Lamont 2019). This theory eliminates all ties of principle between candidates that violate markedness constraints, but does not account for ties between unmarked candidates, as in the tableau in (11). I propose that ties like these are ties of neglect, not ties of principle. They are resolved by other mechanisms like positional faithfulness (Beckman 1997, 1998, Jesney 2011) or reflect directional pressures on prosodic structure. The latter case is exemplified by where different dialects of Arabic insert epenthetic vowels into triconsonantal clusters, mapping underlying /CCC/ onto [CiCC] or [CCiC] (Itô 1989, Mester and Padgett 1994, Elfner 2009, 2016, Torres-Tamarit 2012). [CiCC] is produced when syllables are parsed directionally from right to left or are left-aligned to the prosodic word. Left-to-right syllabification or right-aligned syllables produce [CCiC]. Appealing to the prosodic structure in this way obviates a directional Dep.

(11) /ab/ $\longrightarrow$ [aa] ~ [bb], Step 1

/ab/	*{ab, ba}$^{\Rightarrow}$	Ident
a. ab	W a_1b_2	L
$\longrightarrow$ b. aa		1
$\longrightarrow$ c. bb		1

The tableau in (12) illustrates directional dissimilation; it is identical to the tableau in (5) except for the mode of evaluation. The markedness constraint is evaluated left to right, so the worst locus of violation is $[a_1a_2]$. Candidates (12a,d–f) with this locus are dispreferred to candidates (12b–c) without it. Candidate (12c) is chosen as optimal because candidate (12b) has an additional violation $[a_2a_3]$.

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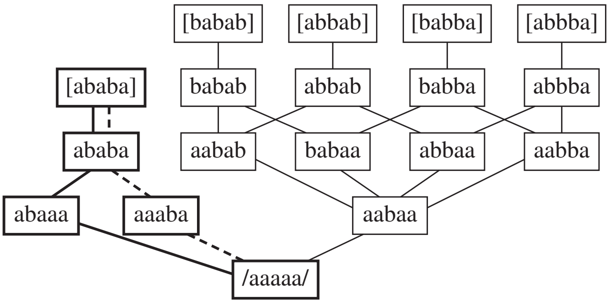
Candidate (12d) is harmonically bounded by candidates (12b–c) and would be harmonically bounded by candidates (12e–f) if *aa were evaluated right to left.

(12) /aaaaa/ ⟶ [ababa], Step 1

/aaaaa/	*aa$^{\Rightarrow}$	Ident
a. aaaaa	W a_1a_2 a_2a_3 a_3a_4 a_4a_5	L
b. baaaa	W a_2a_3 a_3a_4 a_4a_5	1
⟶ c. abaaa	a_3a_4 a_4a_5	1
d. aabaa	W a_1a_2 a_4a_5	1
e. aaaba	W a_1a_2 a_2a_3	1
f. aaaab	W a_1a_2 a_2a_3 a_3a_4	1

The derivational path from this step is represented in (13). At each step, the leftmost or rightmost locus is targeted, and the derivation converges on [ababa] whether *aa is evaluated left to right or right to left. In rule-based phonology, direction of application is related to opacity (Kenstowicz and Kisseberth 1977:chap. 5); a mapping may be transparent when a given rule is applied in one direction and opaque when it is applied in the opposite direction. This is often because applying the rule backward skips foci it would have targeted. For example, applying the rule a → b / ___ a to the UR /aaaaa/ left to right yields [bbbba] and applying it right to left yields [ababa]. This is not the case for directional constraint evaluation. Because removing more loci of violation results in more harmonic improvement, there is no motivation to skip over loci, and derivations only produce transparent mappings.

(13)



The tableau in (14) illustrates directional epenthesis; it is otherwise identical to (7). The markedness constraint is evaluated left to right, and candidates (14a–b,e–h) with the leftmost locus [$b_1b_2b_3$] are dispreferred to those without it (14c–d). In the optimal candidate (14d), the epenthetic [a] removes multiple loci. Note that because positions are defined relative to the input, epenthesis does not affect the indices of loci.

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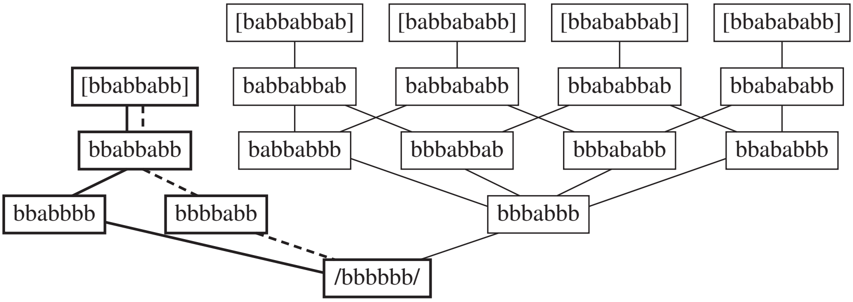
(14) /bbbbbb/ ⟶ [bbabbabb], Step 1

/bbbbbb/	*bbb⇒					DEP
a. bbbbbb	W	$b_1b_2b_3$	$b_2b_3b_4$	$b_3b_4b_5$	$b_4b_5b_6$	L
b. abbbbbb	W	$b_1b_2b_3$	$b_2b_3b_4$	$b_3b_4b_5$	$b_4b_5b_6$	1
c. babbbbb	W		$b_2b_3b_4$	$b_3b_4b_5$	$b_4b_5b_6$	1
⟶ d. bbabbbb				$b_3b_4b_5$	$b_4b_5b_6$	1
e. bbbabbb	W	$b_1b_2b_3$			$b_4b_5b_6$	1
f. bbbbabb	W	$b_1b_2b_3$	$b_2b_3b_4$			1
g. bbbbbab	W	$b_1b_2b_3$	$b_2b_3b_4$	$b_3b_4b_5$		1
h. bbbbbba	W	$b_1b_2b_3$	$b_2b_3b_4$	$b_3b_4b_5$	$b_4b_5b_6$	1

The derivational path from this step is represented in (15). Under either direction of evaluation, the derivation converges on [bbabbabb]. All other outputs require targeting the center of the input in the first step, which is impossible.

(15)



4 Alternative Tie-Breaking Mechanisms

The previous section demonstrated that directional constraint evaluation solves the problem of ties. Loci of violation are harmonically ordered, as are candidates with different loci. Effective tie-breaking mechanisms must be able to distinguish loci by position; this is the only property that is guaranteed to distinguish loci. This section discusses two other mechanisms with this property, gradient alignment and distance-based scaling, and their shortcomings as general solutions to the problem of ties.

Gradient alignment constraints penalize misalignment between two morphological/phonological objects and quantify the violation according to the number of intervening units (McCarthy and Prince 1993, Hyde 2012). They are effective tie-breakers because they distinguish objects by their position. Alignment naturally serves this purpose within the realm of serial prosodification (Pruitt 2010, 2012, Torres-

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Tamarit 2012). However, alignment does not naturally extend into other contexts. The tableau in (16) illustrates the use of alignment to break ties between different epenthesis sites; angled brackets ⟨ ⟩ demarcate a prosodic word and misalignment is quantified over segments. The alignment constraint penalizes segments that intervene between an [a] and the left edge of the prosodic word, and breaks the tie between candidates (16d–f). Candidate (16d) is optimal because its epenthetic [a] is closer to the left edge of its prosodic word than the epenthetic [a] in candidates (16e–f).

(16) Alignment as tie-breaker

⟨bbbbbb⟩	*bbb	Dep	Align([a], L, PrWd, L)
a. ⟨bbbbbb⟩	W 4	L	L
b. ⟨abbbbbb⟩	W 4	1	L
c. ⟨babbbbb⟩	W 3	1	L 1
→ d. ⟨bbabbbb⟩	2	1	2
e. ⟨bbbabbb⟩	2	1	W 3
f. ⟨bbbbabb⟩	2	1	W 4
g. ⟨bbbbbab⟩	W 3	1	W 5
h. ⟨bbbbbba⟩	W 4	1	W 6

Using alignment constraints as tie-breakers requires including in Con the constraints Align(α, L/R, β, L/R), where α is defined over all phonological objects and β is some morphological or phonological category. In order to be a general solution to ties, β must be some domain that encapsulates all possible categories α. This is because when β is absent, the alignment constraint is vacuously satisfied, and ties are not broken. β cannot be defined morphologically because there is no guarantee that any morphological category is present in all candidates. β can also not be defined phonologically in a theory of HS with gradual prosodification (Elfner 2009, 2016, Pruitt 2010, 2012, Torres-Tamarit 2012, 2014). The example above assumes that a prosodic word was built prior to epenthesis: /bbbbbb/ → ⟨bbbbbb⟩ → ⟨bbabbbb⟩ → ⟨bbabbabb⟩ → [⟨bbabbabb⟩]. However, if epenthesis occurs first, then the tie is not broken, because all candidates vacuously satisfy the alignment constraint. It is infeasible to require prosodification to occur before segmental processes because there are a number of cases where prosodification is crucially ordered after segmental processes (Elfner 2009, 2016, Torres-Tamarit 2012, 2014). Further, as a reviewer points out, candidates containing multiple instances of β pose additional problems to this approach. Thus, while alignment constraints can in principle be used as tie-breakers, they impose too many unrealistic restrictions to be effective in general.

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Another way to distinguish violations by position is to adopt distance-based scaling (Inkelas and Wilbanks 2018) within Serial Harmonic Grammar (Legendre, Miyata, and Smolensky 1990, Pater 2012, 2016). Under this proposal, violations are scaled by their distance from the left or right edge of a candidate. As the tableau in (17) illustrates, scaling violations is an effective tie-breaker. Candidates (17b–f) all remove one locus of violation of *a, but are differentiated by which loci remain. Because loci at the left edge incur the highest penalty, it is optimal to target the leftmost locus (17b). In this example, the markedness constraint is scaled while the faithfulness constraint is held constant. Equivalently, the weight of the markedness constraint can be held constant while the faithfulness constraint is scaled linearly in the left index.

(17) Distance-based scaling as tie-breaker, $f(x) = 2x$, Step 1

/aaaaa/	*a f(right-index)	IDENT 5	$\mathcal{H}$
a. aaaaa	$-(f(5) + f(4) + f(3) + f(2) + f(1))$		−33
→ b. baaaa	$-(f(4) + f(3) + f(2) + f(1))$	−1	−25
c. abaaa	$-(f(5) + f(3) + f(2) + f(1))$	−1	−27
d. aabaa	$-(f(5) + f(4) + f(2) + f(1))$	−1	−29
e. aaaba	$-(f(5) + f(4) + f(3) + f(1))$	−1	−31
f. aaaab	$-(f(5) + f(4) + f(3) + f(2))$	−1	−33

While an effective tie-breaker, distance-based scaling has the disadvantage of producing unattested windows of faithfulness.[2] The tableau in (18) illustrates the fourth step of the derivation begun by the tableau in (17). Because the weight of the markedness constraint falls while the weight of the faithfulness constraint remains constant, there is an index beyond which repairs cannot be made, similar to the catching-up pathology discussed by O'Hara (2016). The derivation converges after changing the leftmost three segments: /aaaaa/ → baaaa → bbaaa → bbbaa → [bbbaa].

[2] The proposal by Riggle and Wilson (2005) to cleave constraints into multiple position-specific constraints also predicts windows of faithfulness. Their model was proposed to account for local optionality in pOT, which, as Kimper (2011) demonstrates, can be modeled in HS without any special machinery.

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(18) Word-final window of faithfulness with a linear scale, $f(x) = 2x$, Step 4

bbbaa	*a f(right-index)	IDENT 5	$\mathcal{H}$
→ a. bbbaa	$-(f(2) + f(1))$		−6
b. bbbba	$-f(1)$	−1	−7
c. bbbab	$-f(2)$	−1	−9

If, following Inkelas and Wilbanks (2018), nonlinear scaling functions are allowed, then windows of faithfulness can occur inside words. This effect is illustrated in the tableau in (19). The weight of *b is scaled quadratically and dips below the weight of IDENT at the third segment. Employing distance-based scaling as a tie-breaker thus has the disadvantage of significantly expanding the typology.

(19) Word-internal window of faithfulness with a quadratic scale, $f(x) = 2(x - 3)^2$

aabaa	*b f(left-index)	IDENT 5	$\mathcal{H}$
→ a. aabaa	$-f(3)$		0
b. aaaaa		−1	−5

5 Conclusion

Tied candidates are problematic in any Optimality Theory framework, as they create uncontrollable variation. Directional constraint evaluation (Eisner 2000, 2002) presents a general solution to the problem of ties, and does so in a way that is consistent with existing work on iterative processes. It is effective in its role as a tie-breaker without introducing other problems that come with relying on gradient alignment or distance-based scaling as tie-breakers.

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