Trial Cancellation in NHG

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1. Vowel Reduction in Dutch

In Dutch, unstressed vowels optionally reduce to [ə] (Kager 1989, Booij 1995). The propensity of a vowel to reduce is affected by a variety of factors; here I will focus on the influence of a vowel's position in metrical structure. As illustrated in (1), an unstressed vowel may reduce whether it is footed or not. But within a word,[1] reduction of a footed [o] or [i] is a prerequisite for reduction of an unfooted [o] or [i]. Put another way, these unfooted vowels may not reduce unless their footed counterparts also reduce. Forms such as *[(ˌfo.no̲).lə̲.(ˈɣi)] are therefore illicit.[2]

(1) a. (ˌfo.no̲).lo̲.(ˈɣi) ‘phonology’
(ˌfo.nə̲).lə̲.(ˈɣi)
(ˌfo.nə̲).lo̲.(ˈɣi)
*(ˌfo.no̲).lə̲.(ˈɣi)

b. (ˌlo.ko̲).mo̲.(ˈti.ef) ‘locomotive’
(ˌlo.kə̲).mə̲.(ˈti.ef)
(ˌlo.kə̲).mo̲.(ˈti.ef)
*(ˌlo.ko̲).mə̲.(ˈti.ef)

c. (ˌfe.li̲).ci̲.(ˈteer) ‘congratulate’
(ˌfe.lə̲).cə̲.(ˈteer)
(ˌfe.lə̲).ci̲.(ˈteer)
*(ˌfe.li̲).cə̲.(ˈteer)

Kager (1989) notes that vowel quality influences the possibility of reduction, and while [o] and [i] show the “footed vowels first” pattern (even in words containing both of these vowels: *(ˌNapo̲)li̲(ˈtaan)* ‘Neapolitan’ and *(ˌcrimi̲)no̲(ˈloog)* ‘criminologist’ obey the restriction), this requirement does not hold for sequences of [e], and it holds weakly, if at all, for sequences of [a]. For example, all combinations of (non)reduction for the underlined vowels in *(ˌeuge̲)ne̲(ˈtiek)* ‘eugenism’ and *(ˌabra̲)ca̲(ˈdabra)* ‘abracadabra’ are licit (though *(ˌabr[a̲])c[ə̲](ˈdabra)* may be a bit worse than other possibilities). Also, certain combinations of non-identical vowels may show different reduction patterns. It is also important that the relevant syllables in these examples are light: heavy syllables resist reduction. In this paper I focus on [o] and [i] in light syllables.

Furthermore, if a word contains two footed unstressed vowels, their reduction is coordinated: either they both reduce or neither does. (It is unclear to me how vowel quality affects this generalization.) An example is shown in (2).

(2) (ˌen.do̲)(ˌkri.no̲)(ˈloχ) ‘endocrinologist’
(ˌen.də̲)(ˌkri.nə̲)(ˈloχ)
*(ˌen.do̲)(ˌkri.nə̲)(ˈloχ)
*(ˌen.də̲)(ˌkri.no̲)(ˈloχ)

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[1] To my knowledge, work on this topic has not explored the extent to which these generalizations hold for domains larger than the word.

[2] The phonetic transcriptions in (1a) and (2) are taken from Nazarov (2019). The words in (1b) and (1c) are rendered orthographically following Kager (1989) except that the underlined vowels are given phonetically.

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In this paper I argue that these facts bear on the question of how best to handle ties in Noisy Harmonic Grammar (NHG; Boersma & Pater 2016), a stochastic framework suitable for analyzing optional phenomena like Dutch vowel reduction. In particular, the facts of Dutch indicate that *trial cancellation* (Hayes & Kaplan to appear), in which the evaluation is aborted and retried in the event of a tie, is the soundest way to resolve ties. This contrasts with *random selection* (Boersma & Pater 2016), whereby one of the tied winners is chosen arbitrarily. I will argue that random selection occasionally produces illicit outputs for Dutch, but trial cancellation does not.

The import of ties in NHG, trial cancellation, and random selection are described in section 2. An analysis of Dutch vowel reduction and the argument for trial cancellation are given in section 3. Section 4 further examines the shortcomings of random selection and possible repairs, and section 5 concludes the paper.

2. Ties in NHG

In NHG, constraint weights are perturbed on each evaluation.[3] Here, I assume this is achieved by adding some noise ϵ to a constraint's base (i.e. unperturbed) weight. This ϵ is a real number drawn from a Gaussian distribution with a mean of 0 and a standard deviation of 1. (Altering the noise characteristics does not materially affect the properties of NHG at issue in this paper.) Each constraint receives noise independently of other constraints, so dominance relationships established by the base weights may be reversed by perturbation, potentially yielding different outputs for the same input across evaluation trials.

For example, the schematic tableau in (3) contains two candidates, each of which incurs one violation of one of the two constraints. These constraints have equal base weights, and the outcome of the competition depends entirely on the noise values ϵ_i and ϵ_j: CandA wins if $\epsilon_i < \epsilon_j$, and CandB wins if $\epsilon_i > \epsilon_j$. Because $\epsilon_i = \epsilon_j$ is vanishingly improbable, the likelihood of a tie in this tableau is negligible even though a tie would result in the equivalent non-noisy evaluation.

(3)

/input/	C_1 $5{+}\epsilon_i$	C_2 $5{+}\epsilon_j$	H
(☞) a. CandA	-1		$-5-\epsilon_i$
(☞) b. CandB		-1	$-5-\epsilon_j$

In fact, it is generally impossible—or more accurately, vanishingly improbable—for two candidates with distinct violation profiles to tie in NHG simply because of the extreme unlikelihood that perturbed weights will lead to identical scores. The lone exception to this arises in the avoidance of negative weights. Weights must remain non-negative in (N)HG (Keller 2000, Pater 2009): with a negative weight, constraints end up rewarding configurations they are intended to penalize, and harmonic bounding relationships are destroyed.

But even with base weights confined to non-negative territory, the noise added to constraint weights risks generating negative perturbed weights. To forestall this possibility, Boersma & Pater (2016) adopt *clipping:* when perturbation leads to a negative weight, that negative weight is replaced by zero. If both C_1 and C_2 are clipped in (3), CandA and CandB tie, with scores of 0.[4]

How is such a tie resolved? Two proposals exist in the literature. Under *random selection* (Boersma & Pater 2016), one of the tied winners is chosen at random to be the output of the evaluation. Under *trial cancellation* (Hayes & Kaplan to appear), the evaluation is discarded and attempted again with new noise values until a unique winner emerges. Hayes & Kaplan argue for trial cancellation on the basis of harmonic bounding: if a constraint that is responsible for harmonic bounding is clipped, the harmonically bounded candidate and its bounder will tie. This is illustrated in (4), in which C_2 is clipped; CandA harmonically bounds CandB by virtue of the latter's C_2 violation. The harmonically bounded candidate—a

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[3] See Hayes (2017) and Kaplan (2021) for discussion of alternative implementations of NHG.

[4] Clipping itself is the culprit here, not the fact that negative weights are clipped to zero specifically. As long as all negative weights are converted to the same the value, ties can result, though the scores of the tied candidates will vary depending on the value to which weights are reset.

form that should not win under any circumstances—ties with CandA in this tableau and is therefore a possible output under random selection. But trial cancellation nullifies the evaluation. Because the best a harmonically bounded candidate can do when negative weights are disallowed is tie with its bounder(s), trial cancellation closes its sole path to victory.

(4)

/input/	C_1 5	C_2 0	H
(☞) a. CandA	-1		-5
(☞) b. CandB	-1	-1	-5

Clipping and trial cancellation, Hayes & Kaplan argue, are necessary to preserve harmonic bounding in the sense of excluding harmonically bounded candidates from the set of possible winners. They couch their argument in hypothetical examples like (4); they offer no example from an actual language that exemplifies the situation just described. In the next section I show that Dutch vowel reduction presents just the sort of configuration sketched in (4). Therefore the combination of harmonic bounding and clipping constitutes a genuine challenge to random selection, and trial cancellation is the preferable method for resolving ties.

Hayes & Kaplan focus exclusively on simple harmonic bounding, in which one candidate has a proper subset of another's violation marks. I will show below that their system of clipping and trial cancellation also extends to collective harmonic bounding (Samek-Lodovici & Prince 1999) in which two or more candidates team up to prevent the harmonically bounded candidate from winning even though none has a proper subset of the harmonically bounded candidate's violation marks. However, care is needed when wading into the waters of collective harmonic bounding in HG. As Prince (2003) observes, candidates that are collectively harmonically bounded and therefore impossible outputs in OT may, with the right combination of violation profiles, actually win outright in HG, no ties and random-selection luck needed.

The issue is illustrated schematically in (5) with tableaux adapted from Prince (2003). In both tableaux, CandB is collectively harmonically bounded (and therefore an impossible output) in OT: $C_1 \gg C_2$ favors CandA, and the opposite favors CandC. That result transfers to HG for (5a) but not for (5b). In (5a), as long as $w(C_1) \neq w(C_2)$, CandB will be inferior to one of its competitors; one such situation that favors CandA is shown here. The best CandB can do is tie with one or both (and given the violation profiles shown here, it must be both) of its bounders. Its status is therefore exactly analogous in all relevant respects to that of CandB from (4) in terms of its prospects of winning. But in (5b), there are sets of weights under which CandB beats its competitors, as illustrated in this tableau. Prince identifies the crucial property that distinguishes these tableaux: CandB has fewer total violation marks than at least one of its bounders in (5b) but not in (5a).

(5) a.

/input/	C_1 2	C_2 1	H
☞ a. CandA		-2	-2
b. CandB	-1	-1	-3
c. CandC	-2		-4

b.

/input/	C_1 2	C_2 1	H
a. CandA		-4	-4
☞ b. CandB	-1	-1	-3
c. CandC	-4		-8

Because CandB in (5b) can win outright, trial cancellation does us no good if we want to make this candidate an impossible output. But the proper conclusion is not that HG allows harmonically bounded winners, or that trial cancellation has limited utility, but that CandB is not in fact harmonically bounded in (5b) under HG. This follows if we take the sensible position that harmonically bounded candidates are those that cannot be the sole winner under any combination of (allowable—i.e. non-negative) weights (on analogy with harmonic bounding in OT, where a candidate is favored under no ranking). CandB in (5b) obviously does not meet this criterion; in fact, we can view (5b) as a demonstration that CandB is not harmonically bounded there. Approaching the tableau from the point of view of OT leads us astray in our thinking about the relationships between candidates that foster harmonic bounding. Because OT and HG differ in how harmony is computed, it is not surprising that the conditions under which candidates are harmonically bounded in those theories also differ.

Dutch vowel reduction presents both simple and collective harmonic bounding, and the kind of collective harmonic bounding it presents is of the sort in (5a), which, as I have just argued, is the only kind of collective harmonic bounding in HG. We will see that trial cancellation adequately addresses all instances of harmonic bounding encountered in the analysis of Dutch, and on that basis I surmise that trial cancellation (in tandem with clipping) suffices to keep all harmonically bounded candidates from winning in NHG.

3. Analysis

Reduction is treated here as a process that enhances the contrast between stressed and unstressed vowels.[5] It is driven by the two constraints in (6). These are positional markedness constraints that prohibit vowel features from appearing in weak positions (e.g. Ito 1988, Lombardi 1994, 1995, 2001, Zoll 1997, 1998, Walker 2011). Reduction to [ə] satisfies these constraints, I assume, because [ə] (as the unmarked vowel) lacks features altogether. These constraints are similar to positional augmentation constraints (Smith 2005) in that they require unstressed syllables to be less prominent than stressed syllables. While *VFeat-σ̆ motivates reduction in all unstressed syllables, *VFeat-σ̆-Ft targets footed syllables specifically: the smallest domain containing one of these syllables and a stressed syllable (the foot) is smaller than the smallest domain containing an unfooted syllable and a stressed syllable (perhaps the prosodic word). In this sense footed unstressed syllables are closer to stressed syllables than unfooted syllables are, so reducing footed unstressed syllables is most consequential in terms of distinguishing stressed syllables from their neighbors.

(6) a. *VFeat-σ̆: assign −1 for each unstressed full vowel
 b. *VFeat-σ̆-Ft: assign −1 for each footed unstressed full vowel

Reduction is penalized by the two constraints Max(Height) and Max(Color). These constraints make use of feature classes (Padgett 1995): Height includes the features [high] and [low], and Color includes [back] and [round].[6] Each constraint assigns −1 to any candidate in which at least one member of the relevant feature class has been deleted. Because reduction to [ə] requires deletion of all features, this generally means that a reduced vowel incurs one violation of each Max constraint. The analysis is illustrated in (7) with base weights drawn from a simulation reported below. All possible winners under NHG are marked with (☞), assuming only positive weights (and therefore setting aside clipping) for the moment; given the right combination of noise values assigned to each constraint, any of candidates (a–c) could win. Candidate (d), however, is harmonically bounded by candidate (b) and thus cannot win as long as weights remain positive. With weights restricted to positive numbers, then, the analysis produces all and only the attested forms for (1a) and the other words in (1) with two unstressed vowels, just one of which is footed.[7]

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[5] See Nazarov (2019) for a very different analysis.

[6] Some work (e.g. Odden 1991, Walker 2011) includes [ATR] in the class Height. That choice is compatible with the current analysis.

[7] Recall that in words with [e] and [a] (e.g. *(ˌeuge̲)ne̲(ˈtiek)* ‘eugenism,’ *(ˌabra̲)ca̲(ˈdabra)* ‘abracadabra’), the illicit reduction pattern exemplified by *[(ˌfono)lə(ˈɣi)] is possible. With the current constraints, *(ˌeug[e̲])n[ə̲](ˈtiek)*, e.g., is harmonically bounded, just as *[(ˌfono)lə(ˈɣi)], is. This can be remedied by adopting constraints against unfooted [a] and [e], which will penalize the bounder *(ˌeug[ə̲])n[e̲](ˈtiek)* and render *(ˌeug[e̲])n[ə̲](ˈtiek)* no longer harmonically bounded. Such an addition would not affect (7), where no [a] or [e] is present.

(7)

/fonoloɣi/	*VFEAT-σ̆ 0.365	*VFEAT-σ̆-Ft 0.557	MAX(Ht) 0.235	MAX(Col) 0.235	H
(☞) a. (ˌfono)lo(ˈɣi)	−2	−1			−1.287
(☞) b. (ˌfonə)lo(ˈɣi)	−1		−1	−1	−0.835
(☞) c. (ˌfonə)lə(ˈɣi)			−2	−2	−0.94
d. (ˌfono)lə(ˈɣi)	−1	−1	−1	−1	−1.392

The analysis also correctly handles words with two footed unstressed vowels. In (8), the illicit forms are collectively harmonically bounded by the two licit candidates and therefore only the latter are possible outputs when weights must be positive. When the sum of the weights of the faithfulness constraints is greater than the sum of the weights of the markedness constraints, candidate (a) wins. Candidate (b) wins in the opposite situation. A four-way tie would emerge if the summed markedness weights equalled the summed faithfulness weights, but recall that the odds of that are negligible.

(8)

/endokrinoloχ/	*VFEAT-σ̆ 0.365	*VFEAT-σ̆-Ft 0.557	MAX(Ht) 0.235	MAX(Col) 0.235	H
(☞) a. (ˌendo)(ˌkrino)(ˈloχ)	−2	−2			−1.844
(☞) b. (ˌen.də)(ˌkri.nə)(ˈloχ)			−2	−2	−0.94
c. (ˌendo)(ˌkri.nə)(ˈloχ)	−1	−1	−1	−1	−1.392
d. (ˌen.də)(ˌkrino)(ˈloχ)	−1	−1	−1	−1	−1.392

In (7) and (8), clipping is both a help and a hindrance. Because the illicit combinations of (un)reduced vowels are harmonically bounded, they cannot win outright absent the negative weights that clipping disallows. However, clipping makes it possible for the harmonically bounded candidates to tie with their bounders and thus be one of several candidates with the best scores. In (7), if *VFEAT-σ̆-Ft is clipped, candidates (b) and (d) tie; under the right perturbed weights, those two candidates can beat the others. In (8), if all four constraints are clipped, a four-way tie emerges.

In the situations just described, random selection will choose an illicit candidate to be the output half the time. Trial cancellation will discard these evaluations, and illicit outputs will never occur. To explore how likely ties in this analysis are, I submitted the tableaux in (7) and (8) to OTSoft's NHG tool (Hayes et al. 2013), once with random selection and again with trial cancellation (OTSoft settings: 100,000 learning trials; 100,000 testing trials; initial plasticity = 0.01; final plasticity = 0.001). The weights shown in (7) and (8) are representative of the weights OTSoft arrived at, regardless of how ties were resolved. Candidates' output frequencies are shown in (9). The three illicit forms' frequencies of 0.4% under random selection are small but notable in contrast with the fact that they never appear under trial cancellation.

(9)

		Frequency	
Input	**Candidate**	**Random Selection**	**Trial Cancellation**
/fonologi/	(ˌfo.no)lo.(ˈgi)	0.414	0.434
	(ˌfo.nə)lo.(ˈgi)	0.241	0.226
	(ˌfo.nə)lə(ˈgi)	0.341	0.341
	*(ˌfo.no)lə(ˈgi)	0.004	0.000
/endokrinoloχ/	(ˌen.do)(ˌkri.no)(ˈloχ)	0.412	0.414
	(ˌen.də)(ˌkri.nə)(ˈloχ)	0.580	0.586
	*(ˌen.do)(ˌkri.nə)(ˈloχ)	0.004	0.000
	*(ˌen.də)(ˌkri.no)(ˈloχ)	0.004	0.000

Because the constraints all have base weights close to zero, clipping is a real possibility. Increasing those weights would minimize the likelihood of clipping and thus reduce the illicit forms' frequencies as close to zero as one would like (though exactly 0% could never be achieved), thus putting random selection on par with trial cancellation. In the simulations shown here, though, OTSoft has difficulty arriving at sufficiently high weights because competing licit candidates put contradictory pressure on those weights. For example, for candidate (a) in (8) to win, the sum of the weights of the two Max constraints must be greater than the sum of the weights of the two *VFeat-σ̆ constraints; for candidate (b) to win, the opposite must hold. Similar tension exists in (7). For example, for candidate (b) to beat candidate (c), the Max constraints must together outweigh *VFeat-σ̆; the opposite result requires the opposite relationship. Thus the licit candidates pull constraint weights in opposite directions, and those weights are never allowed to stray too far from their starting point of zero.

4. Improving Random Selection

It is possible to arrange things so that random selection does not produce any illicit outputs in the context of the simulations reported above. This section discusses two strategies (changing the starting points for weights and increasing plasticity) that improve random selection's performance and one that does not (increasing the number of learning trials). It should be borne in mind, though, that random selection cannot categorically exclude the illicit forms at issue; it can only make them very improbable. In contrast, these outputs are truly impossible under trial cancellation, which discards the evaluations that would otherwise give the harmonically bounded candidates a chance to win.

By setting the starting point for weights sufficiently above zero, the risk of clipping can be minimized. Weights will remain near their starting point for the reasons described above, and the new starting points need not be very large. The simulation described in section 3 with random selection produces none of the illicit forms if the starting point is set to 3. (With a weight of 3, a constraint has about a 0.1% chance of undergoing clipping.)

Likewise, increasing the plasticity of weights during the learning cycles allows them to move away from zero more quickly. The simulation in section 3 with random selection does not produce any illicit form if initial plasticity is set to 1. In that situation, all four constraints arrive at base weights greater than any of the weights in (7) or (8) (*VFeat-σ̆: 4.444; Max(Height): 2.556; Max(Color): 2.556; *VFeat-σ̆-Ft: 0.983).

However, increasing the number of learning cycles (while leaving starting points and plasticity alone) does not seem to be effective. Even with 10,000,000 learning cycles, each illicit form still emerges with a frequency of around 0.3%. Giving the system a greater number of opportunities to move weights away from zero is insufficient.

To reiterate, the successful strategies described here only render the unwanted outputs less probable, not impossible. Nonetheless, it appears that there are conditions under which random selection is satisfactory, at least as far as Dutch vowel reduction goes. However, trial cancellation needs no fine-tuning of initial conditions and rules out the illicit forms at issue under all arrangements.

5. Conclusion

Dutch vowel reduction shows that the concerns about random selection raised by Hayes & Kaplan (to appear) are not merely hypothetical. The particular collection of licit and illicit forms and the relationships between those forms' violation profiles make ties caused by clipping a genuine possibility. That is not a problem for random selection if the candidates involved in a tie are all attested outputs, but here some of those candidates are not just illicit, but harmonically bounded. Trial cancellation offers a better way to avoid such unwanted outputs than random selection, and it does so under a wider range of conditions. Trial cancellation rules out these harmonically bounded winners categorically; at best, random selection only makes them unlikely.

Furthermore, these results illustrate the importance of maintaining the consequences of harmonic bounding (Kaplan 2021, Hayes & Kaplan to appear). In the analysis of Dutch, harmonic bounding narrows the candidate set that must be contended with, preventing NHG's stochastic evaluations from becoming a true free-for-all. The illicit candidates at issue here violate the same constraints that penalize the attested forms, so they cannot be ruled out by assigning one or more constraints a very high weight: such a move would also hurt the chances of one or more licit candidate's emergence.

Finally, I have also shown that trial cancellation is useful not just for simple harmonic bounding (as Hayes & Kaplan argue), but also for collective harmonic bounding. Arriving at this conclusion required recognition that candidates that are harmonically bounded in OT may not be harmonically bounded in HG. With that insight, it appears that clipping and trial cancellation suffice to preserve the consequences of both simple and collective harmonic bounding in HG, without exception.

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