If *NT and *ND Got in a Fight, Who Would Win?
Ranking Paradoxes and English Postnasal Stop Deletion*

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1 Introduction

According to Pater (2004) and Hayes (1999), the phonetically motivated universal constraint *NT[1] prohibits voiceless (oral) stops after nasals. Pater, in particular, amasses a great deal of evidence that *NT is operative in a wide range of languages and triggers a wide range of phonological processes. Hayes presents experimental evidence that ND clusters are articulatorily easier than NT clusters, and proposes that only phonetically motivated[2] constraints should be allowed into OT. If this is the case, then all languages should obey *NT (to a greater or lesser extent, depending on their particular constraint rankings).

Hyman (2001), on the other hand, presents evidence that specific diachronic changes may lead a language to obey *ND synchronically instead[3], describing in detail the case of Tswana. It is possible, then, that some languages rank *ND $\gg$ *NT and favor NT clusters rather than ND clusters.

What is *not* predicted by OT is that a language might favor both kinds of clusters in different environments. Since constraint domination is absolute, the ranking *NT $\gg$ *ND guarantees that the language in question will disfavor voiceless stops postnasally in *all* environments, and vice versa for the opposite ranking. However, English seems to be just such an impossible language: it favors voiced postnasal stops prevocalically and voiceless postnasal stops word-finally. This situation leads to an apparent ranking paradox and presents a puzzle for any OT analysis.

In section 3, I detail the problem presented by the English data, which actually consists of

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[1]Pater and Hayes write *NC̥. Following Hyman (2001), I write (*)NT to better distinguish the constraint from (*)ND, and use NC as a cover symbol for all nasal-stop clusters.

[2]In Hayes' terms, "grounded".

[3]He also notes (173) the possibility that *ND and other articulatorily "unnatural" constraints might reflect perceptual imperatives. Myers (2002) also emphasizes the importance of perceptual factors, although he relates them to diachronic sound changes rather than directly to constraints.

two ranking paradoxes. (One, as advertized above, is the question of the relative ranking of *NT and *ND. The other, more easily resolved, concerns the relative ranking of MAX-COR and MAX-PER.) In section 4, I present solutions to both paradoxes, and offer preliminary evidence that *ND should be relativized to the syllable-final position to account for the English data.

2 The Constraints

For simplicity of illustration, the initial analysis will be confined to the following four constraints:

*NT Assigns one violation for every sequence of a nasal followed by a voiceless plosive.

*ND Assigns one violation for every sequence of a nasal followed by a voiced plosive.

MAX-COR Assigns one violation for every segment that contains a coronal place node in the input and has not output correspondant.

MAX-PER Assigns one violation for every segment that contains a peripheral (non-coronal) place node in the input and has no output correspondant.

3 The Problem

3.1 *NT Wins: Prevocalic Voiceless Stop Deletion

If the second element of an NC sequence is a voiceless coronal, it may optionally[4] delete before an unstressed vowel, especially in causal speech. This generalization applies both across morpheme boundaries ((1b)) and within morphemes ((1a), where the historical presence of the stop is still seen in the orthography).

(1) a. 'center' → [sɛnɻ][5]
b. 'hunt' → [hʌnt̚]
'hunting' → [hʌnɪŋ]

On the other hand, if the second element of the NC sequence is either voiced or a non-coronal, it *may not* delete:

(2) a. 'tender' → [tɛndɻ], *[tɛnɻ]
b. 'fund' → [fʌnd]
'funding' → [fʌndɪŋ], *[fʌnɪŋ]

(3) a. 'trumpet' → [tɹʌmpət]m *[tɹʌmət]

[4]I am not concerned here with modelling inter- and intra-speaker variation. The grammar I describe is that of a particular speaker at the particular moment that he exhibits this process of deletion.

[5]Other representations of reduced /VntV/ sequences have been proposed or assumed, including [Vr̃V] (Connine & Ranbom 2004) and [Ṽ̆tV] (Zue & Laferriere 1979). The exact nature of the realization of these sequences is a topic of ongoing research; for now, I assume [VnV], but see section 6 for discussion of this phenomenon in connection with coronal flapping.

b. ‘dump’ → [dʌmp̚]
‘dumping’ → [dʌmpɪŋ], *[dʌmɪŋ]

(4) a. ‘amber’ → [æmbɹ̩], *[æmɹ̩][6]

(5) a. ‘trinket’ → [tɹɪŋkət], *[tɹɪŋət]
b. ‘dunk’ → [dʌŋk]
‘dunking’ → [dʌŋkɪŋ], *[dʌŋɪŋ]

(6) a. ‘anger’ → [æŋgɹ̩], *[æŋɹ̩]

These facts are enough to motivate an exhaustive ranking of the four constraints in section 2. To account for the deletion of voiceless coronals ((1)), we need *NT ≫ MAX-COR (that is, not violating *NT is more important than preserving coronals):

(7)

/hʌnt+ɪŋ/	*NT	MAX-COR
☞[hʌnɪŋ]		*
[hʌntɪŋ]	*!	

To account for the preservation of voiced coronals ((2)), we need MAX-COR ≫ *ND (that is, preserving coronals is more important than not violating *ND)[7]:

(8)

/fʌnd+ɪŋ/	MAX-COR	*ND
☞[fʌndɪŋ]		*
[fʌnɪŋ]	*!	

To account for the preservation of voiceless non-coronals ((3) and (5)), we need MAX-PER ≫ *NT (that is, preserving non-coronals is more important than not violating *NT):

(9)

/dʌmp+ɪŋ/	MAX-PER	*NT
☞[dʌmpɪŋ]		*
[dʌmɪŋ]	*!	

To account for the preservation of voiced non-coronals ((4) and (6)), we need MAX-PER ≫ *ND (that is, preserving non-coronals is more important than not violating *ND):

(10)

/æmbɹ/	MAX-PER	*ND
☞[æmbɹ̩]		*
[æmɹ̩]	*!	

To summarize, we have:

(11) MAX-PER ≫ *NT ≫ MAX-COR ≫ *ND

[6] I cannot give inter-morphemic examples for non-coronal voiced stops, since noncoronal ND clusters do not exist word-finally in English. See section 3.2.

[7] Here and elsewhere, other repairs, such as epenthesis or coalescence, are assumed to be ruled out via high ranking of the relevant faithfulness constraints, such as DEP and UNIFORMITY.

3.2 *ND Wins: Word-Final Voiced Stop Deletion

Word-finally[8], a nasal followed by a non-coronal voiced stop is illicit. Words that historically had final non-coronal ND sequences (as indicated by the orthography) have lost the stop.

(12) 'dumb' → [dʌm], *[dʌmb]

(13) 'dung' → [dʌŋ], *[dʌŋg]

If the second element of the NC is either coronal or voiceless, the cluster is licit.

(14) 'hunt' → [hʌnt]

(15) 'fund' → [fʌnd]

(16) 'dump' → [dʌmp]

(17) 'dunk' → [dʌŋk]

Again, these facts are enough to motivate an exhaustive ranking of the four constraints under consideration. To account for the deletion of voiced non-coronals ((12) and (13))[9], we need *ND ≫ MAX-PER (that is, not violating *ND is more important than preserving non-coronals):

(18)

/dʌmb/	*ND	MAX-PER
☞[dʌm]		*
[dʌmb]	*!	

To account for the preservation of voiceless coronals ((14)), we need MAX-COR ≫ *NT (that is, preserving coronals is more important than not violating *NT):

(19)

/hʌnt/	MAX-COR	*NT
☞[hʌnt]		*
[hʌn]	*!	

To account for the preservation of voiced coronals ((15)), we need MAX-COR ≫ *ND (that is, preserving coronals is more important than not violating *ND):

(20)

/fʌnd/	MAX-COR	*ND
☞[fʌnd]		*
[fʌn]	*!	

[8] A search of the CELEX database found no instances of the relevant clusters syllable-finally either.

[9] The underlying forms of words like 'dumb' are most likely not /dʌmb/ but rather /dʌm/, which suggests that it is possible we are dealing with an accident of history and not a productive process. In fact, English does have one possible exception to this generalization: 'iamb', which the CELEX database lists as [ɑjæmb] (Baayen et al. 1995). However, since there actually seems to be variation both among speakers and among utterances between [ɑjəmb] or [ɑjæmb] and [ɑjəm] or [ɑjæm], and since the lack of word-final postnasal voiced non-coronals seems to be otherwise exceptionless, I assume that we really do have a productive generalization, and for convenience of illustration I posit /dʌmb/.

To account for the preservation of voiceless non-coronals ((16) and (17)), we need MAX-PER ≫ *NT (that is, preserving non-coronals is more important than not violating *NT):

(21)

/dʌmp/	MAX-PER	*NT
☞[dʌmp]		*
[dʌm]	*!	

To summarize, we have:

(22) MAX-COR ≫ *ND ≫ MAX-PER ≫ *NT

3.3 A Paradox

The rankings in (11) and (22), repeated here, are incompatible:

(23) a. MAX-PER ≫ *NT ≫ MAX-COR ≫ *ND

b. MAX-COR ≫ *ND ≫ MAX-PER ≫ *NT

Our account as it stands cannot account for the perverse behavior of nasal-stop clusters in English. In one environment, we see avoidance of NT clusters and deletion of coronals. In another environment, however, we see just the opposite: avoidance of ND clusters and deletion of everything *but* coronals. (23) represents, not one, but *two* ranking paradoxes.

All is not lost. Recall that the above accounts do not attempt to derive the environments in which the phenomena in question occur. In order to solve these two paradoxes, for both pairs <*NT, *ND> and <MAX-COR, MAX-PER>, we need to determine the constraints' relative ranking and make the apparent effects of the opposite ranking fall out of something else. The conditioning environments for these phenomena are in fact prime candidates for this "something else".

4 The Solution

4.1 Faithfulness of Coronals: MAX-COR vs. MAX-PER

The first question is whether it is better in English to delete coronals or to delete non-coronals – in other words, we must determine the relative ranking of MAX-COR and MAX-PER. In this section, I propose that the ranking is MAX-PER ≫ MAX-COR and that the facts in section 3.2 that motivated MAX-COR ≫ MAX-PER can be explained otherwise.

There is evidence (Selkirk 1982) that rimes in English are maximally trimoraic: VCC or VVC. That is, superheavy VVCC syllables such as *[tɑjŋk] or *[kæwmp] are illicit. However, VVCC syllables *do* exist if the final C is coronal: 'mind' ([mɑjnd]) and 'paint' ([pejnt]) are licit. It has been proposed that coronals escape the prohibition on superheavy syllables by existing in extrametrical (nonmoraic) positions or "appendices" (e.g., Hall (1992)), while non-coronals are not allowed in appendices and thus do not have this "escape hatch".

I propose that coronals also use appendices as an escape hatch to avoid being deleted by *ND ≫ MAX-PER, MAX-COR: that *ND and *NT simply do not apply to segments in appendices[10]. Now, using the cover constraint NICEAPP to represent undominated constraints on appendices (syllable-final, nonmoraic, contain only certain coronals, etc.), we can recast the analysis from section 3.2. Thus, instead of (20), we have:

(24)

/fʌnd/	NICEAPP	*ND	MAX-COR
☞[.fʌn.(d)]			
[.fʌnd.]		*!	
[.fʌn.]			*!

In other words, it is *only* because coronals can be parsed into appendices that they avoid deletion. Since non-coronals cannot exist in appendices, the escape hatch is not available to them:

(25)

/dʌmb/	NICEAPP	*ND	MAX-PER
☞[.dʌm.]			*
[.dʌmb.]		*!	
[.dʌm.(b)]	*!		

Now we can replace (22) with

(26) NICEAPP ≫ *ND ≫ MAX-COR, MAX-PER, *NT

Unlike the analysis in section 3.2, this ranking does not depend crucially on the ranking MAX-COR ≫ MAX-PER; that is, it is compatible with MAX-PER ≫ MAX-COR. The analysis of final coronals as appendices solves one of the two ranking paradoxes.

4.2 Voicing in NC Clusters: *NT vs. *ND

The second question is whether English obeys *NT or *ND (i.e., which of *NT and *ND is more highly ranked). In this section, I propose that the correct ranking is *NT ≫ *ND and that the facts in section 3.2 that motivated *ND ≫ *NT can be explained otherwise.

Recall that Hyman (2001) notes the possibility that *ND is perceptually driven. It is plausible to suppose that if this is the case, then *ND is only relevant syllable-finally. That is, it seems intuitively reasonable that the [d] in [fʌnd] is much less perceptible than the [t] in [hʌnt], while the [d] in 'undo' ([ʌn.du]) and the [t] in 'unto' ([ʌn.tu]) are much closer in terms of perceptual salience. If this is the case, then the constraint we need is *ND]$_\sigma$ rather than (or perhaps in addition to) *ND.

There is suggestive evidence that the perceptual account of the markedness of syllable-finaly ND clusters is on the right track; for example, Marcel (1980) observes that unskilled spellers have more difficulty with (even coronal) ND clusters word-finally than intervocalically. More compelling evidence can be found in the (English portion of the) CELEX database (Baayen et al.

[10]Note that we cannot simply say that *ND and *NT only apply to tautosyllabic segments. If this were the case, the [t] in words like 'center' could escape deletion by surfacing in the following syllable ([sɛn.tɻ]). See section 6 for a discussion on how to prevent such segements from escaping into appendices.

1995); consider the following relative frequencies of voiceless and voiced coronal oral stops:

(27)

Percentage of Coronal Oral Stops That Are Voiceless		
	After [n]	Elsewhere
Medially	50.05%	66.51%
Finally	66.04%	66.73%

When not preceded by nasals ("Elsewhere"), voiceless stops are slightly preferred to voiced ones – that is, more than 60% of stops are voiceless. This is expected, since voiceless stops are unmarked with respect to voiced ones. In the environment N__...#, however, voiceless stops are *not* favored; the difference between the proportions in these two cells is highly significant. This is the expected effect of *NT. But in the environment N__ #, voiceless stops *are* slightly favored. This is not what we would expect of *NT. However, it is exactly the environment in which *ND]$_\sigma$ would apply, and exactly the effect we would expect if it did apply.

Note that this result is *not* simply a restatement of the generalization being described here. The transcriptions in the CELEX database do not acknowledge the process of [t]-deletion; the lack of postnasal voiceless stops word-medially is therefore *not* due to the deletion processes itself, but instead evidently to some broader imperative.

Now we can replace *ND from section 3.2 with *ND]$_\sigma$[11]. Instead of (18), we have:

(28)

/dʌmb/	*ND]$_\sigma$	MAX-PER
☞[dʌm]		*
[dʌmb]	*!	

And instead of (20), we have:

(29)

/fʌnd/	MAX-COR	*ND]$_\sigma$
☞[fʌnd]		*
[fʌn]	*!	

Thus, we can replace (11) with

(30) MAX-COR ≫ *ND]$_\sigma$ ≫ MAX-PER, *NT, *ND

This ranking does not depend crucially on the relative ranking of *NT and *ND, so it is compatible with *NT ≫ *ND. The second ranking paradox has been resolved.

5 Conclusion

The final ranking is

(31) NICEAPP ≫ *ND]$_\sigma$ ≫ MAX-PER ≫ *NT ≫ MAX-COR ≫ *ND

[11] Since I am resolving the two ranking conflicts seen in section 3.3 orthogonally, the ranking arguments below do not incorporate the reanalysis from section 4.1. See section 5 for the combination of the two revisions.

For the sake of explicitness, I illustrate the correctness of the complete ranking with tableaux for the behavior of postnasal voiceless coronals and voiced non-coronals in both environments. To save space, I omit *ND. Syllable boundaries are shown only when relevant.

(32)

/hʌnt/	NICEAPP	*ND]$_\sigma$	MAX-PER	*NT	MAX-COR
☞[.hʌn.(t)]					
[.hʌnt.]				*!	
[.hʌn.]					*!

(33)

/hʌnt+ɪŋ/	NICEAPP	*ND]$_\sigma$	MAX-PER	*NT	MAX-COR
☞[hʌnɪŋ]					*
[hʌntɪŋ]				*!	

(34)

/dʌmb/	NICEAPP	*ND]$_\sigma$	MAX-PER	*NT	MAX-COR
☞[.dʌm.]			*		
[.dʌm.(b)]	*!				
[.dʌmb.]		*!			

(35)

/æmbɹ/	NICEAPP	*ND]$_\sigma$	MAX-PER	*NT	MAX-COR
☞[æm.bɹ̩]					
[æmɹ̩]			*!		

We have seen solutions to two apparent ranking paradoxes in English and evidence that *ND should be relativized to the syllable-final position. Note that the ranking of *ND at the bottom of the hierarchy in (31) means that it does no work and could theoretically be eliminated from UG entirely. In fact, the proposal as presented here, that *ND is perceptually motivated and should be modified to *ND]$_\sigma$, suggests that *ND *should* be eliminated. However, Hyman (2001) shows that *ND seems to be active in Tswana in environments other than the syllable-final one; eliminating *ND entirely and replacing it with *ND]$_\sigma$ will not work in this case.[12] Further research on the (family of?) *ND constraints is necessary in order to determine whether, in fact, *ND is active in other environments.

6 Unresolved Issues

As was noted in section 3.3, the concern of this paper has been with untangling the apparently conflicting causes for two distinct processes of postnasal stop deletion in English; as such, it has had little to say about *why* these processes occur in the environments where they do. While the solutions to the ranking paradoxes did strongly link the deletion of voiced non-coronals to the word-final position, they completely ignored the triggering environment of voiceless coronal dele-

[12] But see Zsiga et al. (2006) for evidence that *ND is not the relevant constraint in Tswana either.

tion. It is worth taking a moment to sketch an analysis of voiceless coronal deletion that accounts for its conditioning environment. There are two questions to be answered here: first, why does voiceless coronal deletion happen before vowels at all, and second, why does it happen only before unstressed syllables?

With regard to the first question, note that the tableau in (33) is not strictly accurate – there is in fact another candidate that is more harmonic than the indicated winner:

(36)

/hʌnt+ɪŋ/	NICEAPP	*ND]$_\sigma$	MAX-PER	*NT	MAX-COR
☠ [.hʌn.(t).ɪŋ.]					
[.hʌ.nɪŋ.]					*
[.hʌn.tɪŋ.]				*!	

Nothing in the analysis presented here prevents the [t] in 'hunting' from "escaping" into the appendix just like the [d] in 'fund' (and, incidentally, the [t] in 'hunt'). (Recall that, crucially, *ND]$_\sigma$ and *NT do not apply to appendices.) We could eliminate this candidate with the relatively uncontroversial assumption that appendices must be word-final. Note also that the unfortunate winner in (36) does violate a constraint that [hʌnɪŋ] does not: ONSET. Forcing [t] of 'hunting' into the appendix of the first syllable forces the [n] into the coda of that syllable as well (assuming undominated LINEARITY), leaving the following syllable without an onset. ONSET must be ranked, minimally, above MAX-COR:

(37)

/hʌnt+ɪŋ/	NICEAPP	*ND]$_\sigma$	MAX-PER	*NT	ONSET	MAX-COR
☞[.hʌ.nɪŋ.]						*
[.hʌn.(t).ɪŋ.]					*!	
[.hʌn.tɪŋ.]				*!		

The addition of ONSET to the hierarchy above MAX-COR accounts for the fact that deletion occurs before vowels. Accounting for the fact that deletion does *not* occur before stressed vowels is trickier. Intuitively, we want to say that stressed syllables are priveleged positions and license segments that would otherwise be illicit. However, since syllabification information is not present in the input, it is not possible to write a constraint like MAX-COR-STRESSED-SYL that says something like, "Do not delete a coronal segment such that, if it were not deleted, it would be in a stressed syllable". There is no coherent way of determining where a segment "would have been" in this sense. A number of technical solutions suggest themselves: relativizing *NT to all positions but ones in which the T is in the onset of a stressed syllable, a CONTIG-STRESSED-SYL constraint that forbids contiguity violations within or adjacent to a stressed syllable, or a MAX-NICE-COR-STRESSED-SYL constraint that forbids deletion of coronals in exactly those environments that will also cause a following vowel to be stressed. All of these constraints would do the necessary work, but none is attractive. It seems that a satisfactory solution requires a more refined understanding of positional faithfulness, one that can restrict deletion as well as other kinds of faithfulness violations.

One final point. I have assumed all along that the driving force behind the deletion of voiceless coronals in words such as 'hunting' is *NT. It is worth asking whether it is really *NT

that is important here rather than the considerable allophony of [t]. The environment in which [t] deletes looks very similar, except for the presence of the nasal [n], to the environment in which [t] becomes [ɾ]. The sequence [nɾ] seems marked, even across a syllable boundary; perhaps whatever constraint (or group of constraints) causes the flapping of [t] in certain environments (call it, or them, FLAP) is the one that drives deletion of [t] postnasally by dominating MAX-COR: if [t] cannot flap because of the nasal, then it must disappear entirely. In addition, since the word-internal environment for flapping is the same as that for postnasal [t]-deletion (before unstressed syllables)[13], FLAP gives us the problematic environment of [t]-deletion for free (or at least allows us to conclude that the difficulty of deriving this environment is a problem for more than just one phenomenon).

There are two problems with this suggestion. First, while *NT distinguishes between [t] and [d], FLAP distinguishes between [t] and [p]/[k]. Crucially, it does *not* distinguish between [t] and [d], because [d] in fact flaps in exactly the same way as [t]. In other words, FLAP does the work of MAX-PER ≫ MAX-COR, not the work of *NT ≫ *ND. To account for the fact that [t], but not [d], deletes, the FLAP analysis would have to bring in another constraint to ensure the preservation of [d] in the appropriate environments, perhaps MAX-VOICE (to be fair, a plausible step).

A second, and more troubling, problem with the FLAP analysis is that it seems to predict that [t] will delete in more environments than it actually does. In particular, [t] does not delete in comparable environments when it is preceded by coronal sonorants other than [n]; consider 'altar' → [ɑl.tɻ], [ɑl.ɾɻ] and 'ardor' → [ɑɹ.dɻ], [ɑɹ.ɾɻ]. It seems that it is not the coronal place or sonorancy of the preceding consonant (the presumed cause of the markedness of the [Cɾ] sequence), but crucially its nasality. And once the FLAP analysis is forced to specify that flaps are forbidden only after nasals, it is essentially reduced to the *NT analysis by another name.

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[13]Thanks to Armin Mester for this observation.

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