1 Introduction

• An area of active debate in phonological theory: to what extent are phonological processes phonetically natural?
  – “Phonetically natural” generally means either promoting articulatory ease or, on the other hand, creating some sort of perceptual advantage.
  – A large number of phonological processes claimed to be phonetically natural.

• Two relevant phenomena: post-nasal voicing and post-nasal devoicing.
  – In languages that exhibit post-nasal voicing (PNV), nasal + voiceless stop sequences (NTs) are mapped to nasal + voiced stop sequences (NDs).
    (1) Stops voice after nasals in Puyo Pongo Quechua (Orrr 1962)
    a. [kam-ba] ‘yours’   cf. [sinik-pa] ‘porcupine’s’
    b. [hatum-bi] ‘the big one’   cf. [sača-pi] ‘in the jungle’
    c. [wakin-da] ‘the others’   cf. [wasi-ta] ‘the house’
  – In languages that exhibit post-nasal devoicing (PND), NDs are mapped to NTs.
    (2) Stops devoice after nasals in Nasioi (Brown 2017)
    a. tion-p-ant-∅-in   ‘I talked to him’
       talk-him-I-sg-did
    cf. kara-b-ant-∅-in   ‘I followed him’
       follow-him-I-sg-did
    b. manton-t-a-∅-maan   ‘I feel you’
       feel-you-I-sg-do
    cf. oo-d-a-∅-maan   ‘I see you’
       see-you-I-sg-do

• The processes differ in whether or not they are taken to be phonetically natural.
  – PNV is perhaps universally believed to be phonetically natural, due to a combination of articulatory factors (see Pater 1999, Hayes & Stivers 2000).
  > A nasal + fully voiceless stop sequence requires very precise articulatory coordination: voicing ceases at the same time the velum closes.
  > In practice: often the velum closes after voicing has ceased. This results in nasality leaking into the voiceless stop.
  > Fully voicing the post-nasal stop results in greater articulatory ease.
  – PND is believed to be phonetically unnatural (e.g. Beguš 2018). Given the articulatory difficulty associated with NTs, why would a language create them?

• This talk: PND can be seen as a form of contrast enhancement.
  – The idea, following Stanton (2017) (and Hyman 2001:173): all else being equal, the N-ND contrast is less distinct than the N-NT contrast.
  – Speakers employ PND as a way to render the N-NC contrast more distinct.
  – PND is natural not in the sense that it results in articulatory ease, but instead in the sense that it enhances perceptual distinctiveness.

• Proposal is interesting not just because it illuminates a motivation for PND, but also because it bears on the relationship between articulation and perception.
  – PNV and PND are opposites, both in substance and in motivation: one enhances articulatory ease, another enhances contrast distinctiveness.
  – PNV is far more common. Raises the question: why are processes that enhance perceptual distinctiveness relatively uncommon?

Roadmap

• Section 2. Positional asymmetries in PND.
• Section 3. Perception experiment testing the perceptibility of N-ND and N-NT contrast in two contexts: prevocically and word-finally.
• Section 4. Analysis of the typology in Dispersion Theory (Flemming 2002).
• Section 5. Discussion of PND as a series of sound changes (Beguš 2018).
2 Typology and hypotheses

• Here, I provide a brief overview of aspects of the typology of PND.

• First (§2.1), we’ll focus on a typological asymmetry: some languages allow PND word-finally only, but no languages allow PND prevocally only.

• Second (§2.2), I’ll propose a hypothesis as to why this asymmetry exists.

2.1 Typology

• I know of 14 clear cases of PND; these were identified by consulting Hyman (2001), Stanton (2017), and Beguš (2018); all discuss PND.¹

• Many languages with PND (n=9) allow NCs in prevocalic and word-final positions. These can be divided into two classes.

– Some languages exhibit PND word-finally and prevocally, as in (3).

(3) Example: PND in Konyagi (Beguš 2018:704, citing Merrill 2016)

a. PND in word-final position
   æ-jamp ‘millet stalk’
   cf. Bedik [u-ja’mb], Basari [ɔ-ja’mb]
   i-ja’enk ‘be long’
   cf. Bedik [u-ja’ang], Basari [a-ju’ang]

b. PND in prevocalic position
   i-nkɔt ‘pole’
   cf. Bedik [gɾ-ŋɔt], Basari [ɾ-ŋɔt]
   æ-ncɔl ‘caterpillar’
   cf. Bedik [ɡɔ-ŋɔl], Basari [a-ŋɔl]

– Other languages exhibit PND word-finally only, as in (4).

(4) Example: PND in Naman (Crowley 2006b:26-7)

a. PND in word-final position
   /nɔb/ → [nɔmp] ‘fire’
   /aŋɡ/ → [aŋŋɔk] ‘you (sg.)’

b. No PND in prevocalic position
   /bɔlɔs/ → [mbɔlɔs] ‘tree species’
   /iɡɛt/ → [iɡɛt] ‘we (pl. incl.)’

• The rest of the languages (n=5) exhibit PND in prevocalic position, but do not allow word-final NCs. Nasioi (2), for example, does not allow final clusters.

¹Note that I include only the cases where data is provided or easily accessible. There are further cases discussed in Beguš (2018) for which I have not yet checked the original sources.

Table 1: Summary of PND typology

<table>
<thead>
<tr>
<th>Language</th>
<th>Prevocalic PND?</th>
<th>Word-final PND?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avava</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>Crowley (2006a)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kobon</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>Konyagi</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Merrill (2016), Beguš (2018)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Murik</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Blust (2005, 2013)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Naman</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>Crowley (2006b)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nasioi</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Brown (2017)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neverver</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>Barbour (2012)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Páez</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>Rojas Curieux (1998)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shekgalagari</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Lukusa &amp; Monaka (2008), Solé et al. (2010)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southern Italian</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Rohlfis (1949)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tape</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>Crowley (2006c)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tswana</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Hyman (2001), Gouskova et al. (2011)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yaghnobi</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Xromov (1972)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

• Patterns exhibited by each language are summarized in Table 1.

– A ✓ means PND occurs; a ✗ means PND does not occur.

– Cells are grayed out when there is no way to tell whether or not PND occurs (NCs are not allowed in that position). Does not bear on generalizations.

• What’s most interesting about this table is the pattern that is missing.

– All attested patterns are either ✗/✓ or ✓/gray. There is no ✓/✗.

– In words: no language has prevocalic PND without having word-final PND.

• Question: why should prevocalic PND imply word-final PND?
2.2 Hypotheses

• To explain this asymmetry, let us return to the hypothesis that postnasal devoicing is enhancement of the contrast between N and ND.

• To understand how this can be viewed as enhancement, we need to understand what the cues are to the N-ND contrast, and how devoicing could enhance them.
  – Contrasts between Ns and NCs are cued in part by acoustic differences within the segments and segment sequences themselves.
    ➢ NCs have an oral closure and release. Ns don’t (Burton et al. 1992).
    ➢ In some cases, NCs are longer than Ns (e.g., Riehl 2008).
  – They also are cued by differences in the surrounding vowels.
    ➢ All else equal, NC precedes oral vowel and N precedes nasal vowel.
    ➢ Potential difference in F0 of following vowel: vowels following Ts often have higher F0 than vowels following Ds (e.g., Repp 1979 for English).
  – There are reasons to believe that N-NT contrast is more distinct than N-ND.
    ➢ NTs have an overall longer duration than do NDs, including a longer oral release (e.g., Maddieson & Ladefoged 1993, Coetzee & Pretorius 2010).
    ➢ Vowels sometimes shorten before NTs, but not before NDs or Ns (e.g., Maddieson & Ladefoged 1993).
    ➢ Potential larger difference in F0 in N-NT than N-ND: sonorants often pattern like voiced stops (e.g., Repp 1979 for English).
  – Previous results (Kaplan 2008) demonstrate that N-NT is more perceptible than N-ND in final position.

• Typology of PND allows us to make testable predictions regarding the perception of the N-ND and N-NT contrasts. First, the fact that PND exists suggests (5).

(5) Prediction 1:
N-NT should be more discriminable than N-ND in all positions.

• Second, the generalization that prevocalic PND asymmetrically implies word-final PND suggests (6).

(6) Prediction 2:
N-ND should be more discriminable in prevocalic position than in word-final position.

• Reasoning behind (5) is self-explanatory; but (6) needs more explanation.
  – The linking hypothesis between perception and typology that I assume is Licensing by Cue (Steriade 1997, (7)).

(7) Licensing by Cue (Steriade 1997):
If two contexts (C₁, C₂) differ in that some contrast x-y is better-cued in C₁ than in C₂, the presence of x-y in C₂ implies its presence in C₁.

  ➢ Applying this to N-ND: there is reason to believe that it is better-cued in prevocalic position than in final position (see, also, Beddor & Onsuwan 2003).
  ➢ In word-final position, important cues to the contrast (e.g., difference in nasalization of the following vowel) are absent.
  ➢ In some languages, stops are unreleased word-finally; an additional cue to the contrast (presence vs. absence of oral release) is potentially absent.
  ➢ By (7), we can predict that the presence of N-ND in prevocalic position should asymmetrically imply its presence in word-final position.

  ➢ Licensing by Cue is typically used to predict patterns of neutralization, but we can use it to predict patterns of enhancement, too.
  ➢ Enhancement and neutralization are two sides of the same coin: positional asymmetries in the typologies are parallel (Stanton 2017, Flemming 2017).
  ➢ Not surprising: both are reactions to an insufficiently distinct contrast.
  ➢ The typological predictions we can make, given (7) and what we know about the acoustics and perception of the N-ND contrast, are summarized in (8-9).

(8) Predictions regarding neutralization of N-ND

<table>
<thead>
<tr>
<th>Type of language</th>
<th>Prevocalic neutralization</th>
<th>Final neutralization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Possible</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Possible</td>
<td>x</td>
<td>✓</td>
</tr>
</tbody>
</table>

(9) Predictions regarding enhancement of N-ND

<table>
<thead>
<tr>
<th>Type of language</th>
<th>Prevocalic enhancement</th>
<th>Final enhancement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Possible</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Possible</td>
<td>x</td>
<td>✓</td>
</tr>
</tbody>
</table>

  ➢ The predictions in (8) were verified by Stanton (2017), for a typology of 50 languages. The predictions in (9) line up with the findings in §2.1.

• All that remains to be shown is that the perceptual facts are as the typological generalizations suggest.
  ➢ To do this, I designed an AX task that examines listeners’ ability to discriminate N vs. ND and N vs. NT in prevocalic and word-final position.
  ➢ Preview: the perceptual facts align perfectly with the predictions in (5-6).
3 Perception experiment

- Here: acoustic properties of the stimuli, and findings regarding discriminability.

3.1 Materials

- The stimuli were constructed from trisyllabic nonce words, read aloud by a native speaker of (Peruvian) Spanish.\(^2\) Prevocalic forms were constructed as follows:
  - In \(\sigma_1\), onset C varied between /p/, /t/, and /k/ (to keep the task interesting).
  - In \(\sigma_2\), onset C was always /d/ (to limit the number of variables).
  - In \(\sigma_3\), onset C was labial or coronal N, ND, or NT.
  - In all syllables, the nucleus was /a/, and there was no coda.

- Word-final forms created by deleting the final vowel from the prevocalic forms.
  - The idea behind this method: deleting the final vowel gives listeners the best possible chance of hearing NC’s oral portion.
  - True word-final NCs might have quieter releases, or no releases at all.

- The ‘same’ stimuli were constructed by pairing two recordings of the same form. (In one case, padanda, I used the same recording twice, due to speaker error.)

- The ‘different’ stimuli were created by pairing two recordings of different forms. Contrasts were N-ND, N-NT, and ND-NT (we’ll focus on the first two).

- Examples of stimuli follow in Table 2.

<table>
<thead>
<tr>
<th>Table 2: Stimuli examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prevocalic</strong></td>
</tr>
<tr>
<td>kadan(<em>{1})-kadan(</em>{2})</td>
</tr>
<tr>
<td>kadan(<em>{2})-kadan(</em>{1})</td>
</tr>
<tr>
<td>padan(<em>{1})-padan(</em>{2})</td>
</tr>
<tr>
<td>padan(<em>{2})-padan(</em>{1})</td>
</tr>
<tr>
<td>tanda(<em>{1})-tanda(</em>{2})</td>
</tr>
<tr>
<td>tanda(<em>{2})-tanda(</em>{1})</td>
</tr>
<tr>
<td><strong>Word-final</strong></td>
</tr>
<tr>
<td>kadan(<em>{1})-kadan(</em>{2})</td>
</tr>
<tr>
<td>kadan(<em>{2})-kadan(</em>{1})</td>
</tr>
<tr>
<td>padan(<em>{1})-padan(</em>{2})</td>
</tr>
<tr>
<td>padan(<em>{2})-padan(</em>{1})</td>
</tr>
<tr>
<td>tanta(<em>{1})-tanta(</em>{2})</td>
</tr>
<tr>
<td>tanta(<em>{2})-tanta(</em>{1})</td>
</tr>
</tbody>
</table>

\(^2\)The nonce words discussed here were part of a larger set of forms recorded by this speaker (the forms were intended to be used for multiple experiments). Forms were read aloud as a list, with filler words at the beginning and end of the list, twice each.

3.2 Acoustic properties of productions

- To know if (5-6) are applicable, necessary to verify that there are acoustic dimensions along which N-NT is marked by larger differences than N-ND.

- To investigate this, I took five different acoustic measurements from forms ending in -ana (n=6), -anda (n=5), and -anta (n=6).
  - Measurements taken: duration of V\(_1\), duration of consonant(s), duration of oral release, intensity of oral release, and F0 of the first 10 ms. of V\(_2\).
  - For three measures, larger difference between N-NT than N-ND. For the remaining two, no difference. (Never the case that N-ND more different!)

- Overall duration of segment/cluster (Figure 1)
  - Comparison of the durations of N, ND, and NT reveal that ND is longer than N and shorter than NT (both \(p < .001\), linear regression).
  - Pairwise comparisons (Tukey’s HSD) confirm that all three durations are significantly different from each other (all at \(p < .001\)).
• **Duration of oral release according to segment/cluster type (Figure 2)**
  – Comparison of the durations of N, ND, and NT’s oral releases reveal that ND’s is longer than N’s and shorter than NT’s (both $p < .001$, linear regression).
  – Pairwise comparisons (Tukey’s HSD) confirm that all three durations are significantly different from each other (all at $p < .001$).

• **F0 of the vowel following the segment/cluster (Figure 3)**
  – Comparison of the F0 of the vowels following N, ND, and NT reveal that N’s F0 is lower than NT’s ($p < .01$, linear regression).
  – A difference between N and ND is visible, but not significant.
  – Pairwise comparisons (Tukey’s HSD) confirm that the only significant difference is between N and NT ($p < .05$).

• **Oral vs. nasal quality of the following vowel (not pictured)**
  – I did not measure this, due to the low number of tokens (acoustic measures of nasality work best when there are large numbers of tokens; Styler 2022:29).
  – However, prior work documents perseveratory nasalization following N in (peninsular) Spanish (Fernández Planas 2020, Beristain 2021).

• **Overall**: larger acoustic differences between N-NT than N-ND along several dimensions (overall duration, release duration, and F0 of the following vowel).

• Acoustics of the forms are in line with the discussion in §2, and the predictions.
  – Given the differences in overall and release duration, plausible that discrimination of N-NT will be better than that of N-ND, regardless of context.
  – F0 trends and perseveratory nasalization suggest that discrimination of N-ND will be worse in final than in prevocalic position.

3.3 Procedure

• 50 American English speakers were recruited through Amazon’s Mechanical Turk. Participants were compensated for their time.
  – Three participants were excluded because they performed worse than chance.
  – Performing above chance wasn’t hard: overall accuracy was 71%.

• Each trial had an inter-stimulus interval of 250 ms. between the forms. Participants were allowed to listen to each item once and only once.

• Participants selected whether the two words they had just heard were the same word or different words. They had unlimited time to make their selection.
### 3.4 Results

- The results (in Figure 4) are consistent with the hypotheses. Results are presented in $d'$; the higher the $d'$, the more discriminable the contrast.
  - In both contexts, N-NT is more perceptible than N-ND.
  - N-ND is more perceptible in prevocalic position than in word-final position.
- A mixed-effects linear regression finds significant effects for both the identity of the contrast (N-NT vs. N-ND) and the position (prevocalic vs. final).
  - Both fixed effects (Contrast and Position) were sum-coded.
  - Reference level for Contrast is N-NT; reference level for Position is Prevocalic.

(10) Results of statistical model

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>$t$ value</th>
<th>Significant?</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>3.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contrast</td>
<td>-0.50</td>
<td>-4.98</td>
<td>Yes ($p &lt; .001$)</td>
</tr>
<tr>
<td>Position</td>
<td>-1.63</td>
<td>-1.63</td>
<td>Yes ($p &lt; .001$)</td>
</tr>
</tbody>
</table>

- Adding an interaction does not improve model fit ($\chi^2 (1) = 0.15, p = 0.70$), indicating that the N-ND and N-NT contrasts are equally impacted by position.

### 4 Analysis

- My analysis of the PND typology has two main goals:
  - To reflect the motivation for PND – contrast enhancement – in the formalism.
  - To provide an analysis for all and only the PND patterns that exist.
- To achieve these goals, I adopt Flemming’s (2002) Dispersion Theory.
- The analysis presented here largely follows Stanton (2017).

#### 4.1 Dispersion Theory and PND

- The theoretical core of Dispersion Theory is that selection of phonological contrasts is determined by three functional goals.
  1. Maximize the distinctiveness of contrasts.
     * Why? Language is a communicative medium: we want listeners to be able to tell words apart, so the sounds contained in them should be distinguishable.
  2. Minimize articulatory effort.
  3. Maximize the number of contrasts.
     * Why? Because having a larger number of contrasts allows languages to distinguish words without them becoming excessively long.
- These goals inherently conflict. (In (11), the assumption is that the closer a dot is to the edge, the more effort it requires.)

(11) Schematic dispersion of contrasts (from Flemming 2004:237)

- a. Two categories, most separation, more effort.

  ![Two categories](image)

  *Inventory includes only one contrast.*
  *Contrast is maximally distinct.*

- b. Four categories, less separation, more effort.

  ![Four categories](image)

  *Inventory includes more contrasts.*
  *Expanding the inventory moves sounds together.*
  *Maximizing number vs. distinctiveness of contrasts.*

- c. Four categories, least separation, less effort.

  ![Four categories](image)

  *Producing the sounds requires less effort.*
  *Sounds are closer together.*
  *Maximizing distinctiveness vs. avoiding effort.*
• These three goals are formalized as three separate families of constraints.
  
• **Distinctiveness constraints** require that contrasting sounds (or sound sequences) be sufficiently far apart along some acoustic dimension.
  
  – For PND, the distinctiveness of N vs. ND vs. NT is relevant.
  
  – One dimension we can use: overall length of the segment or segment sequence. This is diagrammed in (12).

\[
\begin{array}{c|c|c}
N & ND & NT \\
1 & 2 & 3 \\
\end{array}
\]

– Requirement to have distinct contrasts formalized as a ranked set of constraints requiring a certain auditory distance between forms (MINDIST constraints).

  – MINDIST constraints requiring smaller distances \( \gg \) constraints that require bigger differences. The smaller the distance, the greater the violation.

\[
\begin{array}{c|c|c|c}
& \text{MINDIST} = \text{LENGTH}:1 & \text{MINDIST} = \text{LENGTH}:2 \\
a. \text{N-ND} & * & \text{NT} \\
b. \text{N-NT} & \text{NT} & * \\
\end{array}
\]

– If MINDIST constraints had their pick, all N-NC contrasts would be N-NT. This isn’t the case, so there must be something counterbalancing it.

• **Effort constraints** penalize segment (sequences) that are articulatorily difficult.

  – There is not a general theory of effort associated with Dispersion Theory.
  
  – Usual practice is to motivate these constraints as they become relevant.
  
  – The only relevant constraint here is *NT (Pater 1999; justification in §1).

\[
\begin{array}{c|c|c|c}
\text{PND in prevocalic position} & \text{MINDIST} = \text{LENGTH}:2 & \text{MINDIST} = \text{LENGTH}:2 \\
a. \text{ana}_1 \text{ana}_2 & * & \text{NT} \\
b. \text{ana}_1 \text{ant}_2 & * & \text{NT} \\
c. \text{ana}_1,2 & * & \text{NT} \\
\end{array}
\]

– If MINDIST constraints had their pick, all N-NC contrasts would be N-NT. This isn’t the case, so there must be something counterbalancing it.

• **Contrast preservation** is enforced by *MERGE ((16), Padgett 2003).

\[
\begin{array}{c|c|c|c|c}
\text{PND in word-final position} & \text{MINDIST} = \text{LENGTH}:2 & \text{MINDIST} = \text{LENGTH}:2 \\
a. \text{an}_1 \text{an}_2 & * & \text{NT} \\
b. \text{an}_1 \text{ant}_2 & * & \text{NT} \\
c. \text{an}_1,2 & * & \text{NT} \\
\end{array}
\]

4.2 Word-final and prevocalic PND

• In languages that PND both prevocally and word-finally, N-ND must not be a sufficiently distinct contrast in either position.

• Here, must be the case that MINDIST = LENGTH:2 dominates *NT. Contrast distinctiveness takes priority over effort minimization.

• What about the role of contrast preservation?

  – Maintaining the N-NC contrast is more important than avoiding NTs, so it must be the case that *MERGE \( \gg \) *NT.
  
  – No basis to establish a ranking between *MERGE and MINDIST = LENGTH:2, so I assume they are together in the top tier.

• In prevocalic position, MINDIST = LENGTH:2 is not satisfied, so PND occurs.

\[
\begin{array}{c|c|c|c|c}
\text{PND in prevocalic position} & \text{MINDIST} = \text{LENGTH}:2 & \text{MINDIST} = \text{LENGTH}:2 & \text{MINDIST} = \text{LENGTH}:2 \\
a. \text{ana}_1 \text{ana}_2 & * & \text{NT} \\
b. \text{ana}_1 \text{ant}_2 & * & \text{NT} \\
c. \text{ana}_1,2 & * & \text{NT} \\
\end{array}
\]

• In word-final position, MINDIST = LENGTH:2 is not satisfied, so PND occurs.

4.3 Word-final only PND

• In languages that have PND word-finally only, the MINDIST constraints we currently have are not sufficient.

  – If *NT \( \gg \) MINDIST = LENGTH:2, we expect N-ND in both contexts.
  
  – If MINDIST = LENGTH:2 \( \gg \) *NT, we expect N-NT in both contexts.
  
  – No way to construct an analysis predicting final N-NT and prevocalic N-ND.

• What we need: a constraint that requires a difference of LENGTH:2, only in contexts where other cues to the contrast are missing (i.e., word-finally).
Recall: other cues to N-NC lie in the next vowel (mostly, nasality vs. orality). I’ll refer to this difference as VOWEL QUALITY.

• We can formalize the intuition that one or the other of these differences is needed for N-NC to be sufficiently distinct as (19).

(19) \[ \text{MINDIST} = \text{LENGTH:2} \lor \text{VOWEL QUALITY} \]

one * for every N-NC contrast that does not differ in either LENGTH:2 or VOWEL QUALITY.

• The ranking is the same as above: *MERGE, MINDIST ≫ *NT.

• In prevocalic position, VOWEL QUALITY is present; *NT blocks PND.

(20) No PND in prevocalic position

<table>
<thead>
<tr>
<th>ana₁ and₂</th>
<th>MINDIST = LENGTH:2 \lor VOWEL QUALITY</th>
<th>*NT</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. ana₁ and₂</td>
<td>*MERGE</td>
<td></td>
</tr>
<tr>
<td>b. ana₁ ant₂</td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td>c. ana₁₂</td>
<td>*!</td>
<td></td>
</tr>
</tbody>
</table>

• In word-final position, VOWEL QUALITY is absent; PND occurs.

(21) PND in word-final position

<table>
<thead>
<tr>
<th>an₁ and₂</th>
<th>MINDIST = LENGTH:2 \lor VOWEL QUALITY</th>
<th>*NT</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. an₁ and₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. an₁ ant₂</td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td>c. an₁₂</td>
<td>*!</td>
<td></td>
</tr>
</tbody>
</table>

4.4 An alternative: word-final PND as final devoicing

• Question: why not analyze these languages characterized by §4.3 as exhibiting word-final devoicing, and not PND (Beguš 2018)? Two reasons:

1. Restrictions on final Ds and final NDs do not always parallel each other.
   - Wolof (Ka 1994), Boukhou Saafi (Mbojd 1983), and Basáa (Hyman 2001): word-final NDs licit but word-final Ds are not.
   - Jabém (Bradshaw & Czobor 2005): final Ds are licit but not final NDs.

2. In at least one language, PND varies with neutralization of the N-ND contrast.

• In Neverver (Barbour 2012), the final N-ND contrast is enhanced or neutralized.

(22) Final N-NC alternations in Neverver (Barbour 2012:30-1)

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a. /bor/</td>
<td>→ [mbør]</td>
<td>‘tasteless’</td>
</tr>
<tr>
<td>b. /lablab/</td>
<td>→ [lablamp] ~ [lablam]</td>
<td>‘be big’</td>
</tr>
<tr>
<td>c. /gel/</td>
<td>→ [gel]</td>
<td>‘slice’</td>
</tr>
<tr>
<td>d. /muwag/</td>
<td>→ [muwanj] ~ [muwan]</td>
<td>‘canoe, boat’</td>
</tr>
</tbody>
</table>

• Difficult to characterize this pattern if final-only PND is just final devoicing.

  – We’d have to claim that, in (22), violations of *[-son, +voi]# are repaired through devoicing or deletion of the final D.
  – The latter of these is an unattested repair to *[-son, +voi]# (Steriade 2009).

• Variation is, however, easily captured with constraints already introduced here.

• Only difference from analysis in §4.3: ranking of *MERGE and *NT is variable.

  – When contrast preservation is favored over avoiding NTs, *MERGE ≫ *NT.
  – When avoiding NTs is favored over contrast preservation, *NT ≫ *MERGE.

• In prevocalic position, neither PND nor neutralization occurs.

(23) No PND or neutralization in prevocalic position

<table>
<thead>
<tr>
<th>ana₁ and₂</th>
<th>MINDIST = LENGTH:2 \lor VOWEL QUALITY</th>
<th>*MERGE</th>
<th>*NT</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. ana₁ and₂</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. ana₁ ant₂</td>
<td></td>
<td></td>
<td>*!</td>
</tr>
<tr>
<td>c. ana₁₂</td>
<td></td>
<td></td>
<td>*</td>
</tr>
</tbody>
</table>

• In final position, PND varies with neutralization.

(24) PND and neutralization in word-final position

<table>
<thead>
<tr>
<th>an₁ and₂</th>
<th>MINDIST = LENGTH:2 \lor VOWEL QUALITY</th>
<th>*MERGE</th>
<th>*NT</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. an₁ and₂</td>
<td></td>
<td></td>
<td>*!</td>
</tr>
<tr>
<td>b. an₁ ant₂</td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>c. an₁₂</td>
<td></td>
<td></td>
<td>*</td>
</tr>
</tbody>
</table>

• These facts suggest that the mechanisms that compel PND are different than those that compel word-final devoicing. The two should have distinct analyses.

4.5 PND and aspiration

• In two languages that I know of, word-final NDs are devoiced and aspirated.
These patterns provide further arguments against final-only PND as final devoicing: why should a restriction on final Ds cause devoicing and aspiration? In Kobon, final NDs obligatorily undergo devoicing and aspiration.

- Per Davies (1981:215), /b d g/ have prenasalized (e.g. [mb]) and prenasalized, devoiced, and aspirated (e.g., [mpʰ]) allophones.  

(25) PND and aspiration Kobon (Davies 1981:221,226)  
   a. /kidolmaN/ → [kindolmaN] ‘arrow type’  
   b. /aiuNd/ → [aiunbʱ] ‘story’  
   c. /ar-ab-in/ → [arambin] ‘go (PRES-1SG)’  
   d. /ar-ab/ → [arambh] ‘go (PRES-3SG)’

- A suggestion that these are really aspirated stops, and not just released ones, comes from the transcription of final plain voiceless stops.

(26) Final voiceless stops in Kobon (Davies 1981:220-1)  
   a. /mu-ep/ → [mu-ep] ‘caring for pigs’  
   b. /kie løy/ → [kʰiey] ‘to be hungry’

In Paés (Rojas Curieux 1998), there is variation akin to what we saw in Neverver.

- Final NDs vary between N, ND, and NTʰ ((27), glosses translated by me).

(27) Realization of NDs in Paés (Rojas Curieux 1998:94-98)  
   a. /himba/ → [himba] ‘horse’  
   b. /sʰamb/ → [sʰam] ~ [sʰambʰ] ~ [sʰam] ‘town’  
   c. /kpinda/ → [kpinda] ‘guava’  
   d. /tund/ → [tun] → [tunbʰ] ~ [tun] ‘fast’  
   e. /nenga/ → [nenga] ‘salt’  
   f. /leng/ → [leng] ~ [lengʰ] ~ [len] ‘lame’

- Final voiceless stops are also aspirated, even when they don’t follow nasals.

(28) Realization of final voiceless stops in Paés  
   a. /ndjiʔp/ → [ndjiʔpʰ] ‘face’  
   b. /tsut/ → [tsutʰ] ‘lace-up shoes’  
   c. /sek/ → [sekʰ] ‘sun’


• Proposed analysis extends easily to these cases of PND and aspiration: aspiration can be seen as a further enhancement to N-NC.

5 Alternative: PND as a historical development

- Beguš (2018) argues that all reported cases of PND have arisen from a sequence of three phonetically natural sound changes.
  1. Voiced stops spirantize except after nasals (D → Z / [-nas]).  
  2. Unconditioned devoicing of voiced stops (D → T).  
  3. Unconditioned fortition of voiced fricatives (Z → D).

- Illustration of these changes from Avestan to Yaghnobi (from Beguš 2018:717):

(29) Developments from Avestan to Sogdian to Yaghnobi  

<table>
<thead>
<tr>
<th>Stage</th>
<th>Sound change</th>
<th>Language</th>
<th>N₁₁</th>
<th>Elsewhere</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>d → t</td>
<td>Avestan</td>
<td>band dasa</td>
<td>Sogdian βand ðasa</td>
</tr>
<tr>
<td>2</td>
<td>d → t</td>
<td>Yaghnobi vant *ðasa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>d → t</td>
<td>Yaghnobi vant das</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- One objection to this proposal: evidence that these changes have taken place is lacking or contested in a number of cases (e.g. Downing & Hamann 2021:21).
- Additionally, Beguš’s proposal would have trouble accounting for cases of final-only PND. Why should these sound changes operate only in that position?

To be clear: I do not argue that all cases of PND arose as contrast enhancement. The claim is that it is a possible motivation with a viable synchronic analysis.

- Very plausible that some arose by a mechanism like the one Beguš proposes.

- In these cases, maybe an analysis of PND as contrast enhancement allows for the maintenance and transmission of the pattern (also Beguš 2018:715).

6 Summary

- PND can be seen as contrast enhancement. Asymmetries in the distribution of PND are consistent with an analysis that appeals to contrast distinctiveness.

- Further directions:

  - Proposed analysis can be easily extended to further cases of postnasal laryngeal alternations (i.e. those discussed by Hamann & Downing 2017).

- Open questions:

  - PND is rare. Analysis does not say anything about this; what’s the reason?

  - More generally: when considerations of articulatory ease and perceptual distinctiveness conflict, why is articulatory ease prioritized?
References


