Creteling 2022: The phonology of nasal-stop sequences
July 21-22: questions of computation
Juliet Stanton, NYU

1. Nasal-stop sequences are cross-linguistically common, but their distribution is frequently constrained. Two representative examples come from English and Paéz (isolate, Rojas Curieux 1998).

   - In English, all nasal-stop sequences can occur in prevocalic position. Word-finally, voiceless nasal-stop sequences can occur, but voiced nasal-stop sequences generally can't.

   (1) Distribution of nasal-stop sequences in English

Sequence	[mb]	[nd]	[ŋg]	[mp]	[nt]	[ŋk]
Intervocalic	e[mb]er	ha[nd]le	a[ŋg]er	ha[mp]er	ba[nt]er	hu[ŋk]er
Word-final	la[m] (*la[mb])	ha[nd]	ha[ŋ] (*ha[ŋg])	li[mp]	li[nt]	li[ŋk]

   - In Paéz, voiced nasal-stop sequences surface medially. Word-finally, they can be realized as a plan nasal, a voiced nasal-stop sequence, or a voiceless-nasal stop sequence.[1]

   (2) Realization of nasal-stop sequences in Paéz (Rojas Curieux 1998:94-98)

a.	/himba/	→ [himba]	'horse'
b.	/s^{j}amb/	→ [s^{j}amb] ∼ [s^{j}amp^{h}] ∼ [s^{j}am]	'town'
c.	/kpinda/	→ [kpinda]	'guava'
d.	/tund/	→ [tund] → [tunt^{h}] ∼ [tun]	'fast'
e.	/nenga/	→ [nenga]	'salt'
f.	/leng/	→ [leng] ∼ [lenk^{h}] ∼ [len]	'lame'

2. These data raise questions about the constraints that govern the distribution of nasal-stop sequences.

   - In both English and Paéz, voiced nasal-stop sequences are permitted prevocalically but restricted word-finally, either absolutely or variably. Why might this be?
   - In both English and Paéz, voiceless nasal-stop sequences have a freer distribution, and (in Paéz) can be allophonic variants of voiced nasal-stop sequences. Why might this be?

3. The basic hypothesis: constraints on the distribution of nasal-stop sequences are constraints on contrast.

4. By appealing to contexts in which these contrasts are more or less distinct, we can predict generalizations regarding the distribution of nasal-stop sequences.

   - We'll focus on a few generalizations regarding the distribution of the contrast between nasals and nasal-stop sequences (from Stanton 2016, 2022), and sketch a analysis that appeals directly to contrast.
   - For more, see Stanton (2016, 2018, 2019).

Distribution of voiced nasal-stop sequences

5. The prediction-generating device we're going to use for generalizations regarding the distribution of contrasts is Steriade's (1997) Licensing by Cue hypothesis.

   (3) If two contexts (C_1 and C_2) differ in that some contrast x–y is better-cued in C_1 than it is in C_2, then the presence of x–y in C_2 implies its presence in C_1.

[1] I use the term 'voiceless nasal-stop sequence' to refer to sequences like [nt], where the stop portion of the sequence is voiceless.

6. We'll focus on the contrast between nasals and nasal-stop sequences in prevocalic and word-final positions. To know what we can predict given (3), we need to know a bit about the phonetics.

   - The contrast is marked by two types of cues, internal (cues residing within the segments or sequences themselves) and external (cues residing in nearby segments; see Steriade 1997 on this distinction).
   - Internal cues: the presence of an oral portion and an oral release (e.g. Burton et al. 1992, Riehl 2008). In some cases, a nasal-stop sequence is longer than a plain nasal (citations in the last handout).
   - External cues: a difference in the following vowel. All else being equal, nasals are followed by nasal(ized) vowels and nasal-stop sequences are followed by oral vowels (citations in Stanton 2016).

7. Likely that a prevocalic contrast between a nasal and a nasal-stop sequence is better-cued than a word-final contrast: external cues are only present in prevocalic position. This, together with (3), yields (4-5):

(4) If a contrast between a nasal and a nasal-stop sequence is licensed in word-final position, this asymmetrically implies that the contrast is licensed in prevocalic position.

(5) Predictions regarding types of possible and impossible languages

Type of language	Licensed prevocalically	Licensed word-finally
Possible	✓	✓
Possible	✗	✓
Impossible	✓	✗

8. To test the predictions in (4-5), I conducted a survey documenting positional restrictions on the distribution of nasal-stop sequences, composed of 75 languages.

   - The survey includes 50 languages where nasal-stop sequences are arguably segments.
     - Criterion for segmental status: nasal-stop sequences can appear in positions where other clusters, or other sonority-violating clusters, cannot.
     - Criterion for inclusion: the language must allow oral stops in both prevocalic and word-final position (see Maddieson 1984:67-8 on why nasal-stop segments are best considered a type of oral stop).
   - It also includes 25 languages in which nasal-stop sequences are clusters.
     - Criterion for cluster status: it does not meet the criterion for segmental status.
     - Criterion for inclusion: the language must allow other sonorant-obstruent clusters in both prevocalic and word-final position.

9. The result: all 75 license a prevocalic contrast between a nasal and a nasal-stop sequence. 38 of these languages additionally allow a word-final contrast between a nasal and a nasal-stop sequence.

(6) Results of typological survey

Contrast licensed in both positions	Contrast licensed in prevocalic position only
38 languages, e.g.	37 languages, e.g.
Avava (Crowley 2006a)	Acehnese (Durie 1985)
Paéz (Rojas Curieux 1998)	Lua (Boyeldieu 1985)
Yiddish (Jacobs 2005)	Wardaman (Merlan 1994)

10. A bit of evidence that this restriction is synchronically active comes from Lolovoli (Hyslop 2001:39-42).

    - In Lolovoli, apocope targets word-final vowels. Its frequency varies by speaker and by word, but there are some generalizations that govern its application.

- Vowels following nasals and stops delete, but vowels following nasal-stops don't.
- Apocope also fails to apply after trills, but we'll focus on the stop series.

(7) Apocope in Lolovoli (Hyslop 2001:49–52)

a.	man	'laugh'	<mana>
b.	k^{h}at̪̚	'speak'	<gato>
c.	ma^{n}da	'rotten'	<mada>

- The question to answer: why does an apocope process affecting vowels following nasals and stops fail to apply to vowels following nasal-stop sequences?
  - A clue comes from the fact that word-final stops in Lolovoli are unreleased. So if apocope applied following nasal-stop sequences, the resulting final stop would probably be unreleased.
  - The loss of the nasal-stop's release would probably make it hard to distinguish from a nasal; looks like preserving cues to the contrast takes priority over apocope.

11. Interim conclusion: the predictions in (4-5) are borne out. Appealing to perceptual factors correctly predicts a generalization regarding the distribution of the contrast between nasals and nasal-stop sequences.

Post-nasal devoicing

12. An interesting finding that came out of the survey discussed above: a restriction on final voiced nasal-stop sequences is sometimes accompanied by devoicing.
    - In Paéz (2), neutralization co-varies with contrast maintenance and devoicing.
    - In Naman (Austronesian, Crowley 2006b) and several other closely related languages, word-final voiced nasal-stop sequences are devoiced.

(8) Post-nasal devoicing in Naman (Crowley 2006b:26-7)

/naːb/	→ [naːmp]	'fire'
/aɣug/	→ [aɣuŋk]	'you (sg.)'

13. These patterns look like examples of post-nasal devoicing, a process claimed by most to be phonetically unnatural (e.g. Beguš 2018).
    - The converse of post-nasal devoicing, post-nasal voicing, is cross-linguistically common.

(9) 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'

- Post-nasal voicing is usually believed to be phonetically natural due to a combination of articulatory factors (e.g. Pater 1999, Hayes & Stivers 2000).
  - A sequence with a nasal followed by a fully voiceless stop requires very precise articulatory coordination: voicing must cease at the same time the velum closes.
  - In practice, often the velum closes after voicing has ceased. This lack of synchronization results in nasality leaking into the voiceless stop.
  - It is articulatorily easier to fully voice the post-nasal stop.

- The existence of post-nasal devoicing raises a question: if voiceless nasal-stop sequences are so difficult to articulate, why would a language create them?

14. I'll show here that post-nasal devoicing can be seen as a form of contrast enhancement.

    - The idea (after Hyman 2001:173, Stanton 2016): all else being equal, the contrast between a nasal and a voiced nasal-stop sequence is less distinct than that between a nasal and a voiceless nasal-stop.
      - Reasons to think this: voiceless stops are longer than voiced stops, with longer and louder releases.
      - In addition, voiceless stops often have a higher F0 in the following vowel than do voiced stops, and sonorants often pattern with voiced stops (e.g. Repp 1979 for English).
      - Existing work (summaries in Maddieson & Ladefoged 1993, Riehl 2008) suggests that these differences hold for the oral portion of nasal-stop sequences, too.
    - Post-nasal devoicing is a way to enhance the contrast between a nasal and a voiced nasal-stop sequence.
    - Post-nasal devoicing is natural not in the sense that it results in articulatory ease, but instead in the sense that it enhances perceptual distinctiveness.

15. If post-nasal devoicing is enhancement of a contrast between a nasal and a voiced nasal-stop sequence, we might expect asymmetries in its distribution to parallel the asymmetries observed for neutralization.

    - Licensing by Cue (Steriade 1997) 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; in other domains, positional asymmetries in the typologies are parallel (Stanton 2017, Flemming 2017).
      - Not surprising, from our current perspective: both are reactions to an insufficiently distinct contrast.
    - The predictions we can make regarding asymmetries in the distribution of post-nasal devoicing, or enhancement, are summarized in (11).

(10) If a contrast between a nasal and a nasal-stop sequence is enhanced in prevocalic position, this asymmetrically implies that the contrast is enhanced in word-final position.

(11) Predictions regarding post-nasal devoicing

Type of language	Prevocalic enhancement	Final enhancement
Possible	✓	✓
Possible	✗	✓
Impossible	✓	✗

16. To test these predictions, I identified 14 cases of post-nasal devoicing from Hyman (2001), Stanton (2017), and Beguš (2018). (This survey is in progress.)

17. Nine of the languages allow nasal-stop sequences in both prevocalic and word-final positions. These can be divided into two classes.

    - Some languages exhibit post-nasal devoicing word-finally and prevocalically, as in Konyagi (12).

(12) Post-nasal devoicing in Konyagi (Beguš 2018:704, citing Merrill 2016)

a. Post-nasal devoicing in word-final position

ə̀-jamp	'millet stalk'	*cf.* Bedik [u-jāmb], Basari [ɔ-jămb]
ì-jàenk	'be long'	*cf.* Bedik [u-jàng], Basari [a-jʌ̀ng]

b. Post-nasal devoicing in prevocalic position

ì-nkòt	'pole'	*cf.* Bedik [gɛ-ngɔ́t], Basari [ɛ-ngɔ̀t]
àe-ncəl̰	'caterpillar'	*cf.* Bedik [gɔ-nɟʌ̀l], Basari [ɑ-nɟʌ́n]

- Other languages exhibit post-nasal devoicing word-finally only, as in Naman (13).

(13) Post-nasal devoicing in Naman (Crowley 2006b:26-7)

a. Post-nasal devoicing in word-final position

/naːb/ → [naːmp] 'fire'
/aɣug/ → [aɣuŋk] 'you (sg.)'

b. No post-nasal devoicing in prevocalic position

/bələs/ → [mbələs] 'tree species'
/iget/ → [iŋget] 'we (pl. incl.)'

18. The other five languages exhibit post-nasal devoicing in prevocalic position, but do not allow nasal-stop sequences in final position. Nasioi (14), for example, does not allow final clusters.

(14) Post-nasal devoicing in Nasioi (Brown 2017)

a. tion-p-ant-∅-in 'I talked to him' *cf.* kara-b-ant-∅-in 'I followed him'
talk-him-I-sg-did follow-him-I-sg-did

b. manton-t-a-∅-maan 'I feel you' *cf.* oo-d-a-∅-maan 'I see you'
feel-you-I-sg-do see-you-I-sg-do

19. The patterns exhibited by each language are summarized in Table 1.

- A ✓ means there is post-nasal devoicing; a ✗ means there is no post-nasal devoicing.
- Cells are grayed out when there is no way to tell whether or not post-nasal devoicing occurs (because nasal-stop sequences are not allowed in that position).
- Cases with grayed-out cells do not bear on generalizations about positional asymmetries.

Table 1: Summary of post-nasal devoicing typology

Language Source(s)	Prevocalic devoicing?	Word-final devoicing?
Avava Crowley (2006a)	✗	✓
Kobon Davies (1980, 1981)	✗	✓
Konyagi Merrill (2016), Beguš (2018)	✓	✓
Murik Blust (2005, 2013)	✓	✓
Naman Crowley (2006b)	✗	✓
Nasioi Brown (2017)	✓	
Neverver Barbour (2012)	✗	✓

Páez Rojas Curieux (1998)	✗	✓
Shekgalagari Lukusa & Monaka (2008), Solé et al. (2010)	✓	
Southern Italian Rohlfs (1949)	✓	
Tape Crowley (2006c)	✗	✓
Tswana Hyman (2001), Gouskova et al. (2011)	✓	
Yaghnobi Xromov (1972)	✓	✓

20. What's most interesting about this table is the pattern that is missing.

    - All attested patterns are either ✗/✓ or ✓/gray. There is no ✓/✗.
    - No language has prevocalic post-nasal devoicing without having word-final post-nasal devoicing.

21. Why not analyze languages with final-only post-nasal devoicing as languages with word-final devoicing (Beguš 2018)? It's simpler, but I think there are a couple of suggestions that this is the wrong way to go.

    - Restrictions on final voiced stops and final voiced nasal-stop sequences can operate independently.
      - In Wolof (Ka 1994), Boukhou Saafi (Mbodj 1983), and Basáa (Hyman 2001), word-final voiced nasal-stop sequences are licit but word-final voiced stops are not.
        - ⊳ Ka (1994:56) notes the existence of final devoicing in Wolof:

          > "The phonemes b, j, g when word-final undergo a final devoicing rule. This final devoicing is ignored in the orthography. (In other words, [p], [c], and [k] do occur word-finally, but are allophones of /b/, /j/, and /g/ rather than of /p/, /c/, and /k/.)"

        - ⊳ There is, however, no acknowledgment of a similar process affecting voiced prenasalized stops, and they appear to contrast with voiceless nasal-stop sequences (voiceless prenasalized stops?).

        (15) Voiced and voiceless nasal-stop sequences in Wolof (Ka 1994:74)

a.	démb	'yesterday'	samp	'to erect'
b.	dend	'to be next to'	bant	'stick'
c.	donj	'grain'	pénc	'meeting place'
d.	sëng	'palm wine'	fonk	'to respect'

      - In Jabêm (Bradshaw & Czobor 2005), word-final voiced stops are licit, but word-final voiced nasal-stop sequences are not.
    - In a couple of languages (including Paéz, (2)), post-nasal devoicing varies with neutralization of the contrast between a nasal and a voiced nasal-stop sequence. Further examples from Neverver:

    (16) Final neutralization or devoicing in Neverver (Barbour 2012:30-1)

a.	/bor/	→ [mbor]	'tasteless'
b.	/lablab/	→ [lablamp] ∼ [lablam]	'be big'
c.	/gel/	→ [ŋgel]	'slice'
d.	/muwag/	→ [muwaŋk] ∼ [muwaŋ]	'canoe, boat'

- These patterns become difficult to characterize if word-final post-nasal devoicing is just final devoicing.
  - We would have to claim that, in (16) and similar cases, violations of *[-son, +voi]# are repaired through either devoicing or deletion of the final voiced stop.
  - Deletion of a final voiced stop is an unattested repair to *[-son, +voi]# (Steriade 2009).

22. A further argument against treating final-only post-nasal devoicing as final obstruent devoicing comes from Kobon, where word-final voiced nasal-stop sequences are devoiced and aspirated.

- According to Davies (1981:215), /b/ /d/ and /g/ have prenasalized (e.g. [mb]) and prenasalized, devoiced, and aspirated (e.g., [mpʰ]) allophones.[2]

(17) Post-nasal devoicing and aspiration in Kobon (Davies 1981:221,226)

a.	/kɨdolmaŋ/	→	[kɨndolmaŋ]	'arrow type'
b.	/aiud/	→	[aiuntʰ]	'story'
c.	/ar-ab-in/	→	[aɾambin]	'go (PRES-1SG)'
d.	/ar-ab/	→	[aɾampʰ]	'go (PRES-3SG)'

- A suggestion that these are really aspirated stops (and not just released ones, as is probably true with some transcriptions of "aspirated" stops) comes from the transcription of final plain voiceless stops.

(18) Final voiceless stops in Kobon (Davies 1981:220-1)

a.	/mu-ep/	→ [mu-ep]	'caring for pigs'
b.	/kie löp/	→ [kʰielɵɸ]	'to be hungry'

23. Interim summary: generalizations regarding neutralization and enhancement of the contrast between nasals and voiced nasal-stop sequences are parallel. This is predicted under the approach used here.

Experimental evidence

24. The generalizations established above allow us to make several predictions regarding the perception of contrasts among nasals and nasal-stop sequences (voiced and voiceless).

- The fact that post-nasal devoicing occurs in both prevocalic and word-final position suggests (19).

(19) The contrast between a nasal and a voiceless nasal-stop sequence should be more discriminable than the contrast between a nasal and a voiced nasal-stop sequence in both positions.

- The empirical evidence surveyed above (mainly, parallels in the distribution of neutralization and enhancement), suggests (20).

(20) The contrast between a nasal and voiced nasal-stop sequence should be more discriminable in prevocalic position than in word-final position.

25. To test these, I designed an AX task that tests listeners' ability to discriminate contrasts between nasals, voiced nasal-stop sequences, and voiceless nasal-stop sequences, in prevocalic and word-final positions.

- In an AX task, listeners are played two recordings and asked if they are same or different.
- It is possible to tell how distinct the recordings are by the rate at which listeners distinguish which pairs of forms are "same", and which are "different".

[2] They also have oral allophones, e.g. [b] and [p], but the distribution of these is not relevant here.

26. Stimuli were constructed from trisyllabic nonce words, read by a native speaker of (Peruvian) Spanish.

- The forms used to test the perceptibility of prevocalic contrasts were created by manipulating the identity of the onset consonants in the third syllable.
  - In the first syllable, the onset consonant varied between /p/, /t/, and /k/.
  - In the second syllable, the onset consonant was always /d/.
  - In the third syllable, the onset consonant(s) was a labial or coronal nasal, voiced nasal-stop sequence, or voiceless nasal-stop sequence.
  - The nucleus of each syllable was /a/, and no syllable had a coda.
  - These criteria yield forms like *padanda*, *tadana*, *kadanta*.
- The forms designed to test the perceptibility of word-final contrasts were created by deleting the final vowel of each word.
  - The idea behind this: deleting the final vowel gives listeners the best possible chance of hearing the nasal-stop sequence's oral portion and release.
  - True word-final nasal-stop sequences might have quieter releases, or no releases (as in Lolovoli).
- The 'same' stimuli were constructed by pairing two recordings of the same form.[3]
- The 'different' stimuli were created by pairing two recordings of different forms.
  - Pairs differed in the identity of the third syllable's onset.
  - Comparisons were: nasal and voiced nasal-stop sequence, nasal and voiceless nasal-stop sequence, voiced and voiceless nasal-stop sequences. We will focus on the first two; the third is not relevant.
- Stimuli examples are in (21). The subscripts are there as a reminder that even for the 'same' items, the comparison is between two different recordings.

(21) Examples of stimuli for AX task

	Same	Different
Prevocalic	$kadana_1$-$kadana_2$	kadana-kadanda
	$kadana_2$-$kadana_1$	kadanda-kadana
	$padanda_1$-$padanda_2$	padana-padanta
	$padanda_2$-$padanda_2$	padanta-padana
	$tadanta_1$-$tadanta_2$	tadanta-tadanda
	$tadanta_2$-$tadanta_1$	tadanda-tadanta
Word-final	$kadan_1$-$kadan_2$	kadan-kadand
	$kadan_2$-$kadan_1$	kadand-kadan
	$padand_1$-$padand_2$	padan-padant
	$padand_2$-$padand_2$	padant-padan
	$tadant_1$-$tadant_2$	tadant-tadand
	$tadant_2$-$tadant_1$	tadand-tadant

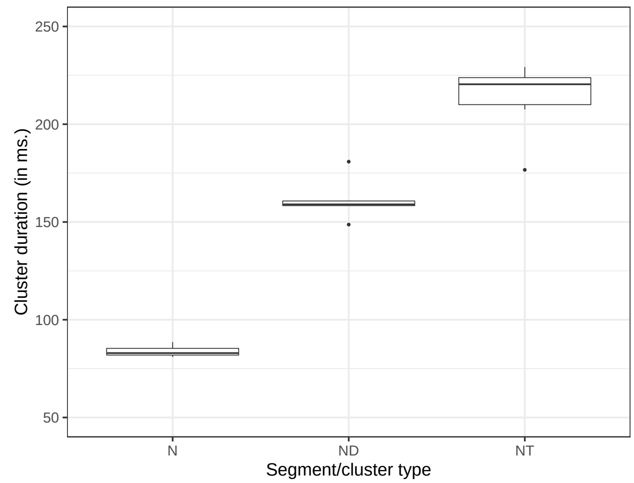
27. To know if (19-20) are applicable, we need to verify that there are acoustic dimensions along which the contrast between a nasal and a voiceless nasal-stop sequence is marked by larger differences than the contrast between a nasal and a voiced nasal-stop sequence.

- I took five different measurements from forms ending in *-ana* (n=6), *-anda* (n=5), and *-anta* (n=6).
- Measurements: duration of the vowel preceding the consonant(s), duration of consonant(s), duration of oral release, intensity of oral release, and F0 of the first 10 ms. of the vowel following the consonant(s).

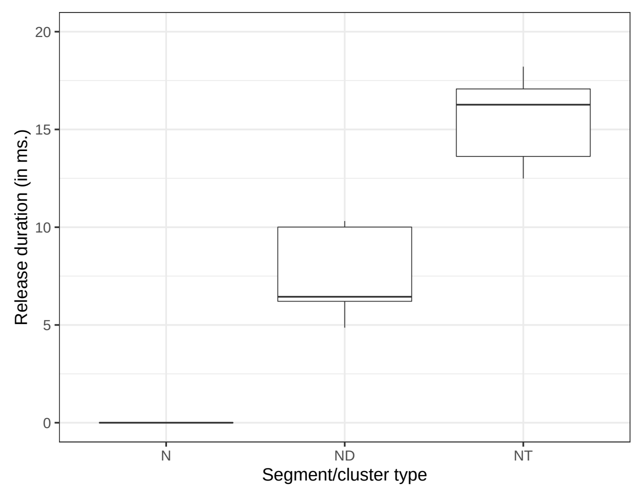
[3]In one case, *pandanda*, I used the same form twice due to speaker error.

28. For three measures, there was a larger difference between a voiceless nasal-stop sequence and a nasal than there was between a voiced nasal-stop sequence and a nasal.

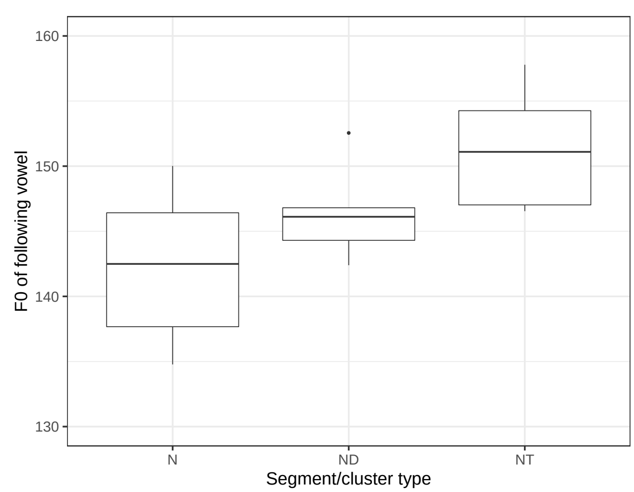
- Overall duration of segment/cluster:
  - Comparison of the durations of nasals, voiced nasal-stop sequences, and voiceless nasal-stop sequences reveal that nasals are shorter than voiced nasal-stop sequences, and voiced nasal-stop sequences are shorter than voiceless nasal-stop sequences (both comparisons $p < .001$, linear regression).
  - Pairwise comparisons (Tukey's HSD) confirm that all three durations are significantly different from each other (all comparisons at $p < .001$).



- Duration of the oral release:
  - Comparison of nasal, voiced nasal-stop, and voiceless nasal-stop's oral releases reveal that the voiced nasal-stop's release is longer than the nasal's and shorter than than the voiceless nasal-stop's (both comparisons $p < .001$, linear regression).
  - Pairwise comparisons (Tukey's HSD) confirm that all three durations are significantly different from each other (all comparisons at $p < .001$).



- F0 of the vowel following the consonant(s):
  - Comparison of the F0 of the vowels following nasals, voiced, and voiceless nasal-stop sequences reveal that the nasal's F0 is lower than the voiceless nasal-stop's ($p < .01$, linear regression).
  - The difference between the nasals and voiced nasal-stops is not significant.
  - Pairwise comparisons (Tukey's HSD) confirm that the only significant difference is between nasals and voiceless nasal-stops ($p < .05$).



29. For the remaining two measures, there was no difference. Crucially, it was never the case that a voiced nasal-stop sequence was more distinct from a nasal than was a voiceless nasal-stop sequence.

- There were no significant differences in the duration of the vowel preceding these three categories.
- There were no significant differences in the intensity of the oral releases.

30. Overall, there are larger differences between a nasal and a voiceless nasal-stop sequence than there are between a nasal and voiced nasal-stop sequence along several acoustic dimensions. These differences are in line with the predictions.

- Given the differences in overall and release duration, plausible that the nasal vs. voiceless nasal-stop contrast is more perceptible than the nasal vs. voiced nasal-stop contrast.
- Differences in F0 suggest that discrimination of the contrast between a nasal and voiced nasal-stop sequence will be worse in final position. (Lack of a following vowel probably relevant for other reasons.)

31. I recruited 50 American English speaking participants through Amazon's Mechanical Turk.

- Three participants performed worse than chance, so their data was excluded.
- Performing above chance wasn't hard; overall accuracy on the task was 71%.

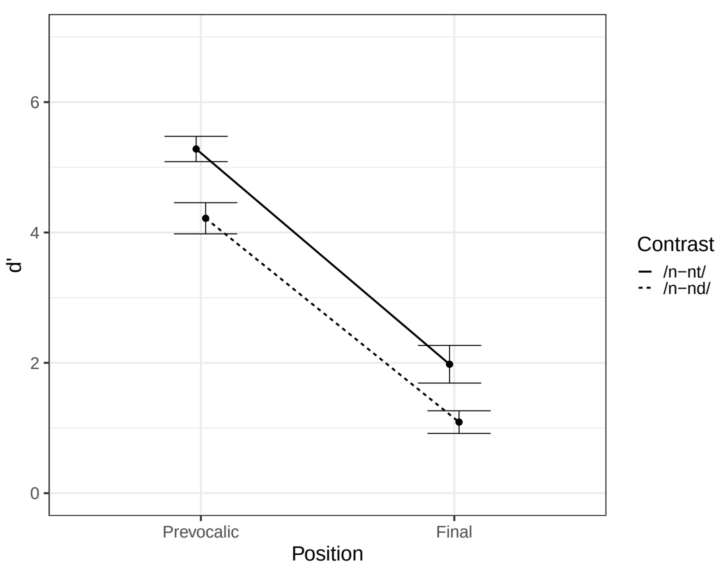
32. Each trial had an inter-stimulus interval of 250 ms. between the forms. The participants were allowed to listen to each item once, and only once.

33. 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.

34. The results (in Figure 1) are consistent with the hypotheses in (19-20). Results are presented in d'; the higher the d', the more discriminable the contrast.

- The contrast between a nasal and a voiceless nasal-stop sequence is more distinct than the contrast between a nasal and a voiced nasal-stop sequence, regardless of context.
- The contrast between a nasal and a voiced nasal-stop sequence is more distinct in prevocalic position.

Figure 1: Perceptibility of contrasts between nasals and nasal-stop sequences, by position



35. A mixed-effects linear regression finds significant effects for both the identity of the contrast (nasal vs. voiceless nasal-stop and nasal vs. voiced nasal-stop) as well as the position (prevocalic vs. final).

- Both fixed effects (Contrast and Position) were sum-coded.
- Reference level for Contrast is nasal vs. voiced nasal-stop; reference level for Position is Prevocalic.
- Interpreting this: the nasal vs. voiced nasal-stop contrast is less perceptible than the nasal vs. voiceless nasal-stop contrast; the contrasts are less perceptible in word-final position.

(22) Results of statistical model

	Estimate	*t* value	Significant?
(Intercept)	3.12		
Contrast	-0.50	-4.98	Yes ($p < .001$)
Position	-1.63	-1.63	Yes ($p < .001$)

36. Adding an interaction does not improve model fit (χ^2 (1) = 0.15, p = 0.70). An interpretation of this is that the perceptibility of both contrasts are equally impacted by position.

Review of Dispersion Theory

37. The analysis I propose is in Dispersion Theory (Flemming 2001 et seq.), so we'll review the basics first.

38. Dispersion Theory holds that selection of phonological contrasts is determined by three functional goals.

(a) 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.)

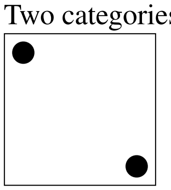
(b) Minimize articulatory effort.

(c) Maximize the number of contrasts.
(Why? Because having a larger number of contrasts allows languages to distinguish words without them becoming excessively long.)

39. These goals inherently conflict. (In (23), the closer a dot is to the edge, the more effort it requires.)

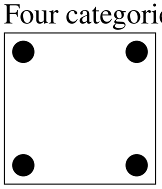
(23) Schematic dispersion of contrasts (from Flemming 2004:237)

a. Two categories, most separation, more effort.



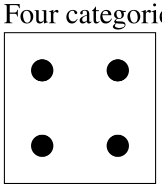
Inventory includes only one contrast.
Contrast is maximally distinct.

b. Four categories, less separation, more effort.



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

c. Four categories, least separation, less effort.



Producing the sounds requires less effort.
Sounds are closer together.
Maximizing distinctiveness vs. avoiding effort.

40. These three goals are formalized as three separate families of constraints.

41. Distinctiveness constraints require that contrasting sounds (or sound sequences) be sufficiently far apart along some acoustic dimension.

- For this analysis, the distinctiveness of nasals vs. voiced and voiceless nasal-stop sequences is relevant.
- One dimension we can use: overall length of the segment or segment sequence (24).

(24) Scale for overall length of nasals and nasal-stop sequences

N	ND	NT →
1	2	3

- 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 dominate constraints that require bigger differences. The smaller the distance, the greater the violation.

(25) MINDIST = LENGTH:1 ≫ MINDIST = LENGTH:2

- MINDIST = LENGTH:1 penalizes contrasts between a nasal and a nasal-stop sequence not differentiated by 1 (by (24)); MINDIST = LENGTH:2 penalizes contrasts not differentiated by 2 (by (24)).

(26)

	MINDIST = LENGTH:1	MINDIST = LENGTH:2
a. N-ND		*
b. N-NT		

- If MINDIST constraints had their pick, all contrasts between a nasal and a nasal-stop sequence would involve a voiceless nasal-stop sequence. This isn't the case, so there must be a counterbalance.

42. Effort constraints penalize segment (sequences) that are difficult to articulate.

- There is not a general theory of effort associated with Dispersion Theory, so the usual practice is to motivate these constraints as they become relevant.
- The only relevant constraint here is *NT (Pater 1999; justification above).

(27) *NT: assign one * for each nasal + voiceless stop sequence.

- Effort constraints limit the range of contrasts. The nasal vs. voiceless nasal-stop contrast is more distinct than the nasal vs. voiced stop contrast, but the former is harder to implement, so it is penalized.

43. Contrast preservation is enforced by *MERGE ((28), Padgett 2003).

(28) *MERGE: assign one * for each pair of input candidates that share an output correspondent.

Analysis

44. In languages that have neutralization and enhancement both prevocalically and word-finally, the contrast between a nasal and a voiced nasal-stop sequence must not be sufficiently distinct in either position.

45. Both phenomena occur due to activity of the same MINDIST constraints. Whether the result is neutralization or enhancement depends on the ranking of other constraints.

- For neutralization, it must be that *NT and MINDIST = LENGTH:2 dominate *MERGE.
  - Contrast is not sufficiently distinct and voiceless nasal-stops are penalized, so neutralization occurs.
  - Same result in prevocalic and word-final positions; MINDIST is not satisfied in either context.

(29) Neutralization in prevocalic position

ana_1 $anda_2$	*NT	MINDIST = LENGTH:2	*MERGE
a. ana_1 $anda_2$		*!	
b. ana_1 $anta_2$	*!		
☞ c. $ana_{1,2}$			*

(30) Neutralization in word-final position

an_1 and_2	*NT	MINDIST = LENGTH:2	*MERGE
a. an_1 and_2		*!	
b. an_1 ant_2	*!		
☞ c. $an_{1,2}$			*

- For enhancement, it must be that *MERGE and MINDIST = LENGTH:2 dominate *NT.
  - The contrast is not sufficiently distinct and neutralization is penalized, so enhancement occurs.
  - Same result in prevocalic and word-final positions; MINDIST is not satisfied in either context.

(31) Enhancement in prevocalic position

ana_1 $anda_2$	*MERGE	MINDIST = LENGTH:2	*NT
a. ana_1 $anda_2$		*!	
☞ b. ana_1 $anta_2$			*
c. $ana_{1,2}$	*!		

(32) Enhancement in word-final position

an_1 and_2	*MERGE	MINDIST = LENGTH:2	*NT
a. an_1 and_2		*!	
☞ b. an_1 ant_2			*
c. $an_{1,2}$	*!		

46. In languages that have enhancement or neutralization word-finally (and not prevocalically), the MINDIST constraints proposed so far are insufficient.

- If *NT dominates MINDIST = LENGTH:2, we expect a contrast between a nasal and a voiced nasal-stop sequence in both contexts.
- If MINDIST = LENGTH:2 dominates *NT, we expect a contrast between a nasal and a voiceless nasal-stop sequence in both contexts.
- Currently, there is no way to construct an analysis predicting final-only neutralization or enhancement.

47. 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 the contrast between a nasal and a nasal-stop sequence lie in the following vowel (mostly, a difference in nasality vs. orality, also possibly F0).
- I refer to this difference as VOWELQUALITY (a shorthand for some specific acoustic property(s)).

48. We can formalize the intuition that one or the other of these differences is needed for a contrast between a nasal and a nasal-stop sequence to be sufficiently distinct as a disjunctive constraint (33).

(33) MINDIST = LENGTH:2 ∨ VOWELQUALITY:
one * for every contrast between a nasal and a nasal-stop sequence that does not differ in either LENGTH:2 or VOWELQUALITY.

49. With this constraint in place, we can model word-final only neutralization and enhancement. The difference between these repairs is, again, a difference in constraint ranking.

- For neutralization, *NT and MINDIST = LENGTH:2 ∨ VOWELQUALITY must dominate *MERGE.
  - In prevocalic position, VOWELQUALITY is present, so nothing happens: *NT blocks enhancement and *MERGE blocks neutralization.

(34) No neutralization in prevocalic position

ana_1 $anda_2$	*NT	MINDIST = LENGTH:2 ∨ VOWELQUALITY	*MERGE
☞ a. ana_1 $anda_2$			
b. ana_1 $anta_2$	*!		
c. $ana_{1,2}$			*!

  - In word-final position, VOWELQUALITY is absent. *NT dominates *MERGE, so neutralization (not enhancement) occurs.

(35) Neutralization in word-final position

an_1 and_2	*NT	MINDIST = LENGTH:2 ∨ VOWELQUALITY	*MERGE
a. an_1 and_2		*!	
b. an_1 ant_2	*!		
☞ c. $an_{1,2}$			*

- For enhancement, *MERGE and MINDIST = LENGTH:2 ∨ VOWELQUALITY must dominate *NT.
  - In prevocalic position, VOWELQUALITY is present, so nothing happens: *NT blocks enhancement and *MERGE blocks neutralization.

(36) No enhancement in prevocalic position

ana_1 $anda_2$	*MERGE	MINDIST = LENGTH:2 ∨ VOWELQUALITY	*NT
☞ a. ana_1 $anda_2$			
b. ana_1 $anta_2$			*!
c. $ana_{1,2}$	*!		

  - In word-final position, VOWELQUALITY is absent. *MERGE dominates *NT, so means that enhancement (not neutralization) occurs.

(37) Enhancement in word-final position

an_1 and_2	*MERGE	MINDIST = LENGTH:2 ∨ VOWELQUALITY	*NT
a. an_1 and_2		*!	
☞ b. an_1 ant_2			*
c. $an_{1,2}$	*!		

50. How would we analyze cases like Kobon (data in (17-18)), where post-nasal devoicing in word-final position is accompanied by aspiration?

- We could add NT^h to the scale in (24), which tracks the length of nasals and nasal-stop sequences.

(38) Scale for overall length of N, ND, NT, and NT^h

N	ND	NT	NT^h →
1	2	3	4

- Introducing the constraint MINDIST = LENGTH:3 ∨ VOWELQUALITY allows us to account for Kobon: in the absence of VOWELQUALITY, the nasal-stop sequence must devoice and aspirate.
  - In prevocalic position, VOWELQUALITY is present, so nothing happens: *NT blocks enhancement and *MERGE blocks neutralization.

(39) No enhancement in prevocalic position

ana_1 $anda_2$	*MERGE	MINDIST = LENGTH:3 ∨ VOWELQUALITY	*NT
☞ a. ana_1 $anda_2$			
b. ana_1 $anta_2$			*!
c. ana_1 ant^ha_2			*!
c. $ana_{1,2}$	*!		

  - Word-finally, VOWELQUALITY is absent. The fact that *MERGE dominates *NT results means that enhancement occurs. MINDIST demands that the voiced nasal-stop sequence devoice and aspirate.

(40) Enhancement in word-final position

an_1 and_2	*MERGE	MINDIST = LENGTH:3∨ VOWELQUALITY	*NT
a. an_1 and_2		*!	
☞ b. an_1 ant_2			*
c. an_1 $ant^h{}_2$			*
c. $an_{1,2}$	*!		

- How to block aspiration in languages that have only post-nasal devoicing? Probably, propose a constraint that disprefers aspirated nasal-stop sequences (or just aspirated stops).

51. It is impossible to derive systems that have enhancement or neutralization in prevocalic position only.
    - This is a feature of MINDIST constraints: it is impossible to formulate a MINDIST constraint that penalizes more distinct contrasts to the exclusion of less distinct contrasts.
    - As languages like this are unattested, this is an argument for appealing to constraints on contrast.

My thoughts

52. The parallel between neutralization and enhancement is consistent with the claim that the distribution of nasal-stop sequences is controlled by constraints on contrast.
53. Throughout, I did not distinguish nasal-stop segments and nasal-stop clusters. I have yet to find evidence that this distinction is relevant to phonotactics. This is in line with Gouskova & Stanton (2021), I think.
54. A lingering question: why is enhancement of a contrast less common than neutralization? Cases of post-nasal devoicing are rare compared to cases of restrictions on final voiced nasal-stop sequences.
    - This is not the first time I've seen this. For example:

  - In most languages, I think, a contrast between oral and nasal vowels is neutralized when its cues are compromised (e.g. after a nasal).
  - However, in a relatively small number of languages, mostly in South America, the contrast is enhanced through environmental shielding (Herbert 1986, Stanton 2018).
- Flemming (2017) notes this discrepancy, and hypothesizes that it may be due to biases in description: neutralization is obvious; enhancement can be phonetically subtle.
- It would be interesting to know if the typology of neutralization and enhancement supports this idea: does the prevalence of enhancement change as it becomes more salient?

Your thoughts?

References

Barbour, Julie (2012). *A grammar of Neverver*. De Gruyter Mouton.

Beguš, Gašper (2018). Post-nasal devoicing and the blurring process. *Journal of Linguistics* 55, 689–753.

Blust, Robert (2005). Must sound change be linguistically motivated? *Diachronica* 22, 219–269.

Blust, Robert (2013). *The Austronesian Languages*. Asia-Pacific Linguistics, Canberra.

Boyeldieu, Pascal (1985). *La langue lua ('niellim')*. Cambridge University Press, Cambridge.

Bradshaw, Joel & Francisc Czobor (2005). *Otto Dempwolff's Grammar of the Jabem Language in New Guinea*. University of Hawai'i Press, Honolulu.

Brown, Jason (2017). Postnasal Devoicing in Nasioi. *Oceanic Linguistics* 56, 267–277.

Burton, Martha, Sheila Blumstein & Kenneth N. Stevens (1992). A phonetic analysis of prenasalized stops in Moru. *Journal of Phonetics* 20, 127–142.

Crowley, Terry (2006a). *The Avava language of central Malakula (Vanuatu)*. Pacific Linguistics, Canberra.

Crowley, Terry (2006b). *Naman: a vanishing language of Malakula (Vanuatu)*. Pacific Linguistics, Canberra.

Crowley, Terry (2006c). *Tape: a declining language of Malakula (Vanuatu)*. Pacific Linguistics, Canberra.

Davies, H. John (1980). *Kobon phonology*. Pacific Linguistics Series B, No. 87, Canberra: Australian National University.

Davies, John (1981). *Kobon*. North-Holland Publishing Company, Amsterdam.

Durie, Mark (1985). *A grammar of Acehnese on the basis of a dialect of north Aceh*. Foris Publications, Leiden.

Flemming, Edward (2001). Scalar and categorical phenomena in a unified model of phonetics and phonology. *Phonology* 18, 7–44.

Flemming, Edward (2004). Contrast and perceptual distinctiveness. Hayes, Bruce, Robert Kirchner & Donca Steriade (eds.), *Phonetically-Based Phonology*, Cambridge University Press, Cambridge, 232–276.

Flemming, Edward (2017). Dispersion Theory and Phonology. *The Oxford Research Encyclopedia of Linguistics*.

Gouskova, Maria & Juliet Stanton (2021). Learning complex segments. *Language* 97, 151–193.

Gouskova, Maria, Elizabeth Zsiga & One Tlale (2011). Grounded constraints and the consonants of Setswana. *Lingua* 12, 2120–2152.

Hayes, Bruce & Tanya Stivers (2000). Postnasal voicing. Ms., University of California, Los Angeles.

Herbert, Robert K. (1986). *Language Universals, Markedness Theory, and Natural Phonetic Processes*. Mouton de Gruyter, Berlin.

Hyman, Larry M. (2001). The limits of phonetic determinism in phonology: *NC revisited. Hume, Elizabeth V. & Keith Johnson (eds.), *The role of speech perception in phonology*, Academic Press, Cambridge, MA, 141–185.

Hyslop, Catriona (2001). *The Lolovoli dialect of the North-East Ambae language, Vanuatu*. Pacific Linguistics, Research School of Pacific and Asian Studies, Australian National University, Canberra.

Jacobs, Neil G. (2005). *Yiddish: A linguistic introduction*. Cambridge University Press, Cambridge.

Ka, Omar (1994). *Wolof phonology and morphology*. University Press of America, Lanham, MD.

Lukusa, Stephen T. M. & Kemmonye C. Monaka (2008). *Shekgalagari grammar: a descriptive analysis of the language and its vocabulary*. The Centre for Advanced Studies of African Society (CASAS), Cape Town.

Maddieson, Ian (1984). *Patterns of sounds*. Cambridge University Press, Cambridge.

Maddieson, Ian & Peter Ladefoged (1993). Partially nasal consonants. Huffman, Marie & Rena Krakow (eds.), *Nasals, Nasalization, and the Velum*, Academic Press, San Diego, CA, 251–301.

Mbodj, Chérif (1983). *Recherches sur la phonologie et la morphologie de la langue Saafi: le parler de Boukhou*. Ph.D. thesis, Université de Nice, Nice.

Merlan, Francesca C. (1994). *A Grammar of Wardaman: A Language of the Northern Territory of Australia*. Mouton de Gruyter, Berlin.

Merrill, John (2016). Konyagi post-nasal devoicing? Ms., University of California, Berkeley.

Orrr, Carolyn (1962). Ecuador Quichua Phonology. Elson, Benjamin (ed.), *Studies in Ecuadorian Indian languages*, Summer Institute of Linguistics, Norman, OK, 60–77.

Padgett, Jaye (2003). The Emergence of Contrastive Palatalization in Russian. Holt, D. Eric (ed.), *Optimality Theory and Language Change*, Kluwer Academic Publishers, Dordrecht.

Pater, Joe (1999). Austronesian nasal substitution and other nc effects. Kager, René, Harry van der Hulst & Wim Zonneveld (eds.), *The prosody-morphology interface*, Cambridge University Press, Cambridge, 310–343.

Repp, Bruno H. (1979). Relative Amplitude of Aspriation Noise as a Voicing Cue for Syllable-Initial Stop Consonants. *Language and Speech* 22, 173–189.

Riehl, Anastasia K. (2008). *The phonology and phonetics of nasal obstruent sequences*. Ph.D. thesis, Cornell University, Ithaca, NY.

Rohlfs, Gerhard (1949). *Historische Grammatik der Italienischen Sprache und ihrer Mundarten*. Francke, Bern.

Rojas Curieux, Tulio (1998). *La lengua páez: una vision de su gramática*. Bogotá: Ministerio de cultura.

Solé, Maria-Josep, Larry M. Hyman & Kemmonye C. Monaka (2010). More on post-nasal devoicing: The case of Shekgalagari. *Journal of Phonetics* 38, 299–319.

Stanton, Juliet (2016). Predicting distributional restrictions on prenasalized stops. *Natural Language and Linguistic Theory* 34, 1089–1133.

Stanton, Juliet (2017). *Constraints on the Distribution of Nasal-Stop Sequences: An Argument for Contrast*. Ph.D. thesis, MIT, Cambridge, MA.

Stanton, Juliet (2018). Environmental shielding is contrast preservation. *Phonology* 35, 39–78.

Stanton, Juliet (2019). Constraints on contrast drive nasal cluster dissimilation. *Phonology* 36, 655–694.

Stanton, Juliet (2022). Post-nasal devoicing as contrast enhancement. Talk presented at WCCFL 40.

Steriade, Donca (1997). Phonetics in Phonology: The Case of Laryngeal Neutralization. Ms., University of California, Los Angeles.

Steriade, Donca (2009). The Phonology of perceptibility effects: The P-map and its consequences for constraint organization. Hanson, Kristin & Sharon Inkelas (eds.), *The Nature of the Word: Studies in Honor of Paul Kiparsky*, MIT Press, Cambridge, MA, 151–179.

Xromov, Al'bert (1972). *Jagnobskij jazyk*. Nauka, Moskva.