

Constraints on contrast motivate nasal cluster dissimilation*

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Abstract. Many languages exhibit nasal cluster dissimilation (NCD), in which an illicit sequence of co-occurring nasal-stop clusters is modified in some way (e.g. $NC_1VNC_2 \rightarrow N_1VNC_2$). This article discusses generalizations in the typology of NCD and claims that NCD is driven by constraints on contrast distinctiveness: it occurs preferentially in those environments where the first NC (NC_1 , in NC_1VNC_2) is most confusable with a plain nasal consonant. I propose an analysis that appeals to auditory factors and provide acoustic and perceptual evidence that is consistent with it.

1 Introduction

In a number of languages, the distribution of nasal-stop sequences (NCs) is restricted. The focus of this article is on a class of effects termed nasal cluster dissimilation (NCD) by McConvell (1988), which together identify a cross-linguistic dispreference for the co-occurrence of NCs within a single word (so *ambada* and *abanda*, but **ambanda*). The two most common strategies to avoid such a configuration are deletion of the first NC (NC_1)'s oral component and deletion of the second NC (NC_2)'s nasal component; other strategies are discussed briefly in Section 6.1. In (1–2), italicized examples confirm that the alternations are conditional on the presence of multiple underlying NCs.

- (1) Ngaju Dayak: deletion of NC_1 's oral component (Blust 2012:372)
- | | | | | |
|----|-------------|---|-------------|----------------|
| a. | /maN+bando/ | → | [ma-mando] | 'turn against' |
| | /maN+bagi/ | → | [mam-bagi] | 'divide' |
| b. | /maN+gundu/ | → | [ma-ŋundul] | 'wrap up' |
| | /maN+gila/ | → | [maŋ-gila] | 'drive crazy' |
- (2) Gurindji: deletion of NC_2 's nasal component (McConvell 1988:138)¹
- | | | | | |
|----|---------------|---|---------------|--------------------|
| a. | /kaŋju+mpal/ | → | [kaŋju-pal] | 'across below' |
| | /kajira+mpal/ | → | [kajira-mpal] | 'across the north' |
| b. | /kanka+mpa/ | → | [kanka-pa] | 'upstream' |
| | /kani+mpa/ | → | [kani-mpa] | 'downstream' |

What kind of constraint drives NCD? Many analysts (e.g. Alderete 1997, Blust 2012) have argued that alternations like (1–2) are driven by a co-occurrence constraint that penalizes words containing more than one NC. Others (Jones 2000, to some extent Herbert 1986) argue that NCD is perceptually motivated: in NC_1VNC_2 , the first NC (NC_1) may be confusable with a nasal consonant, as its oral portion is preceded and followed by a nasal consonant, the latter of which likely induces some amount of anticipatory nasalization in the preceding vowel (so, $[NC_1\tilde{V}NC_2]$ is difficult to tell

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¹ I use IPA transcriptions throughout the article; this means that the transcriptions in the cited sources are often adapted.

apart from $[N_1\tilde{V}NC_2]$). Repairs like (1–2), then, are motivated by a desire to avoid forms in which the contrast between NC_1 and a plain nasal consonant, N , is insufficiently distinct.

This article provides support for the claim that NCD is perceptually motivated. Sections 2–3 discuss several implicational generalizations that hold over the structures targeted by NCD, propose analyses that appeal to perceptual factors, and present two case studies supplemented with acoustic data. Section 4 presents results of a perceptual experiment that are consistent with assumptions of the analysis. Section 5 verifies a larger typological prediction of the analysis: if NCD does not reflect a dispreference for the co-occurrence of nasal clusters per se, but rather a dispreference for $NC\tilde{V}$, languages that exhibit NCD should ban $NC\tilde{V}$ across the board (regardless of the source of the vowel's nasality) and languages that allow $NC\tilde{V}$ should not exhibit NCD.

The results described in this article provide further support for the claim that constraints on the distribution of NCs are constraints on contrast (Stanton 2016b, 2018a), and by extension for the claim that constraints on contrast are a necessary component of the synchronic grammar (e.g. Flemming 2002, Gallagher 2010). Alternatives and broader implications for our understanding of the larger typology of dissimilatory processes are discussed in Section 6.

2 The right-hand context: generalizations and analysis

The next two sections present results of a typological survey consisting of 67 languages in which the distribution of NCs is restricted in the environment of Ns or other NCs.² These languages were identified from reference grammars and previous literature (e.g. Meeussen 1963, Herbert 1977, McConvell 1988); more details and references for each language are in the appendix. This section focuses on generalizations regarding the right-hand context (e.g. NC_2 , in NC_1VNC_2) and proposes an analysis linking these generalizations to acoustic and perceptual factors: NCD is more likely when the post- NC_1 vowel is more nasalized.

2.1 Preconsonantal vs. prevocalic nasals

While the term “nasal cluster dissimilation” implies that the restriction holds only over co-occurring NCs, many languages that exhibit NCD also prohibit nasal-stop clusters from preceding onset nasals (also Herbert 1986, McConvell 1987, *a.o.*). The relationship between the two restrictions is implicational: almost all languages that ban NC_1VN_2V ban NC_1VNC_2 , but the reverse does not hold. In (3–5), the surveyed languages are categorized according to the nature of the restrictions they impose. Decisions that led to these classifications were usually based on a combination of multiple sources; for more details see the appendix.

- (3) Restrictions on NC_1VNC_2 and NC_1VN_2V
 (21 languages, including Luganda; Herbert 1976)
- | | | | | |
|----|----------------|--------------|-----------------------|------------------|
| a. | $*NC_1VNC_2$: | /n+bumba/ | → [m:umba], *[mbumba] | ‘I mould’ |
| | | cf. /n+bala/ | → [mbala], *[m:ala] | ‘I count’ |
| b. | $*NC_1VN_2V$: | /n+limi/ | → [n:imi], *[ndimi] | ‘tongues’ |
| | | cf. /n+lere/ | → [ndere], *[n:ere] | ‘leather strips’ |

² I do not consider languages where bans on co-occurring Ns and/or NCs occur as part of a network of consonantal co-occurrence restrictions, as it is possible that more general considerations of identity or similarity avoidance are in play. For a representative example see Muna (van den Berg 1989, Coetzee & Pater 2008).

- (4) Restriction on NC₁VNC₂ only
(43 languages, including Ngaju Dayak; Blust 2012)
- | | | | | |
|----|-------------------------------------|-------------|--------------------------|----------------|
| a. | *NC ₁ VNC ₂ : | /maN+bando/ | → [mamando], *[mambando] | ‘turn against’ |
| b. | NC ₁ VN ₂ V: | /maN+deŋen/ | → [mandeŋen], *[maneŋen] | ‘make deaf’ |
- (5) Restriction on NC₁VN₂V only
(3 languages, including Bolia; Mamet 1960, gloss translations mine)
- | | | | | |
|----|-------------------------------------|-----------|-----------------------|--------------|
| a. | NC ₁ VNC ₂ : | [lwáŋgá], | pl. [ɲáŋgá], *[náŋgá] | ‘thicket(s)’ |
| b. | *NC ₁ VN ₂ V: | [loímo], | pl. [nímo], *[ɲímo] | ‘honor(s)’ |

The languages in (5) – Bokote, Bolia, and Sango – are worthy of further discussion. The only basis for categorizing Bokote in this way is Meeussen’s (1963:28) statement that evidence for NCD comes from “only a few cases of the type -boman-”, and a footnote that lists five other relevant roots. There is no evidence of alternations and the cited dictionary (Hulstaert 1957) does not discuss restrictions on the distribution of NCs. Thus it is unclear what the strength of Meeussen’s evidence is. In the case of Bolia, Mamet (1960:22) writes that the plural suffix is realized as [ɲ] before a vowel, but as [ɲ] “if the root has as its first consonant a singleton nasal” (translation mine). But the illustrative examples provided are consistent with an alternative analysis under which [ɲ] cannot precede [i]. Finally, it is unclear if Sango actually exhibits NCD. Meeussen’s discussion provides one example ([imono] ‘castor oil’, cl. 12 [akavono]), but Samarin’s (1967) grammar contains many words with co-occurring Ns and NCs (e.g. p. 35-6: [ngunzá] ‘manioc leaves’, [ndóndó] ‘brain’, [mbéní] ‘some’). Treating these languages as “NC₁VN₂V only” is conservative, as it is quite possible that they do not exhibit NCD at all. These possible counterexamples aside, the generalization above is that a ban on NC₁VN₂V asymmetrically implies a ban on NC₁VNC₂.

2.2 Hypothesis and analysis

I hypothesize that the implicational generalization in (3-5) can be attributed to differences in the realization of the post-NC₁ vowel in NC₁VNC₂ vs. NC₁VN₂V. It has been documented for many languages that coda (or non-prevocalic) nasals induce more regressive nasal coarticulation than do onset (or prevocalic) nasals.³ A survey of nasalization patterns by Jeong (2012) documents this pattern for French and Modern Greek; Krakow (1993) documents it for American English; Herbert (1977) documents it for a number of languages, including Pashto, Malagasy, and Delaware; and Schourup (1973:191) concludes, on the basis of a large survey, that “in no language examined are vowels nasalized before prevocalic nasals when they are not also nasalized before all pre-consonantal and word-final nasals.” Thus in many languages, the first vowel in NC₁VNC₂ is likely more nasalized than the corresponding vowel in NC₁VN₂V.

This acoustic difference could lead to a difference in the relative perceptibility of the contrast between NC₁ and N (N–NC₁). Let us hypothesize that N–NC₁ is more confusable when NC₁ is followed by a nasalized vowel than when it is followed by an oral vowel. Furthermore, let us hypothesize that the greater the amount of nasalization, the more confusable N–NC₁ is. If this is correct, two asymmetries should hold. First, the acoustic distance between N–NC₁ before an oral consonant (C₂, (6a)) should be greater than the acoustic distance between N–NC₁ before onset or

³ I use the term “coarticulatory nasalization” in this article to refer to all types of non-contrastive nasalization. The distinction between allophonic and true coarticulatory nasalization is not relevant here.

coda N_2 (6b-c). Second, the acoustic distance between N - NC_1 before an onset nasal (6b) should be greater than the acoustic distance between N - NC_1 before a coda nasal (6c).

(6) Hypothesized perceptual asymmetries

| Comparison | Relative acoustic distance | |
|--|----------------------------|---------|
| a. $\Delta NC_1 VC_2 V - N_1 VC_2 V$ | Greater | |
| b. $\Delta NC_1 VN_2 V - N_1 VN_2 V$ | Lesser | Greater |
| c. $\Delta NC_1 VNC_2 V - N_1 VNC_2 V$ | | Lesser |

We can now derive the generalizations in (3–5) with constraints that penalize insufficiently distinct contrasts. The proposed analysis is framed in Dispersion Theory (Flemming 2002), as its MINDIST constraints allow the grammar to reference a contrast's perceptibility in different contexts. To capture the observed generalizations, I propose that NC must be followed by a sufficiently oral vowel for N - NC to be distinct, and I encode this requirement as a set of MINDIST constraints that penalize N - NC contrasts in which NC is followed by a vowel with increasing amounts of nasality.

To formalize these constraints, I assume that language learners divide vowels into a finite number of categories, according to the average amount of coarticulatory nasalization they exhibit. I refer to these categories as $ORAL_x$, where x is the category number. The referents of these category numbers are likely language-specific, as are patterns of coarticulatory nasalization (see Section 2.4 for more discussion on this point). For an analysis of the generalizations in (3–5), however, we only need to reference three categories: $ORAL_1$ ($V/_N$ coda), $ORAL_2$ ($V/_N$ onset), and $ORAL_3$ ($V/_C$).

(7) $ORAL_x$ values for analysis of (3-5)

| $ORAL_x$ value | Referents |
|----------------|--|
| 1 | $V/_N$ coda (e.g. <i>amanda</i>) |
| 2 | $V/_N$ onset (e.g. <i>amāna</i>) |
| 3 | $V/_C$ (e.g. <i>amāda</i> , <i>amada</i>) |

Given three $ORAL$ categories, we can formulate two constraints on the N - NC contrast: MINDIST N - NC : V - $ORAL_2$ and MINDIST N - NC : V - $ORAL_3$ (8–9).⁴

(8) MINDIST N - NC : V - $ORAL_2$:

Assign one violation for each contrast between N and NC in which the following vowel does not belong to category of 2 or higher along the $ORAL$ scale.

(9) MINDIST N - NC : V - $ORAL_3$:

Assign one violation for each contrast between N and NC in which the following vowel does not belong to category 3 or higher along the $ORAL$ scale.

Contrasts that satisfy and violate (8–9) are as follows. MINDIST N - NC : V - $ORAL_2$ is satisfied by contrasting pairs like *amāna-ambāna* ($ORAL_2$) and *amāda-ambāda* ($ORAL_3$), but violated by pairs like *amānda-ambānda* or *amānda-ambānta* ($ORAL_1$). MINDIST N - NC : V - $ORAL_3$ is satisfied by only *amāda-ambāda* ($ORAL_1$), and violated by any pairs with a nasal in second position (e.g.

⁴ The MINDIST constraints in (8–9) make the implicit assumption that only N - NC contrasts are affected by the amount of nasalization in a following vowel. I am not aware of evidence that any other consonantal contrasts are similarly affected.

amana-ambana, ORAL₂). I assume that cross-linguistic differences in the righthand context for NCD reflect differences in the ranking of MINDIST constraints on the ORAL scale with respect to *MERGE (Padgett 2003), a constraint that penalizes neutralization.

- (10) *MERGE (Padgett 2003):
No output word has multiple correspondents in the input.

The input-output mapping /amanda_i, ambanda_j/-[amanda_i, ambanda_j] satisfies *MERGE; the mapping /amanda_i, ambanda_j/-[amanda_{i,j}], with neutralization of N-NC, violates it. A factorial typology of (8-10) predicts three types of system. If *MERGE >> MINDIST N-NC: V-ORAL₂, MINDIST N-NC: V-ORAL₃, NCD will not occur. One language instantiating this ranking is English, where contrasting forms like *amanta-ambanta* are licit, even though *mb* is followed by a vowel whose ORAL category is 1 (11). I indicate ORAL values with numeric subscripts following the relevant segment, and correspondence indices with alphabetic subscripts.

- (11) English: *MERGE undominated, no NCD

| | /amanta/ _i | /ambanta/ _j | *MERGE | MD N-NC: V-ORAL ₂ | MD N-NC: V-ORAL ₃ |
|----|---------------------------------------|--------------------------------------|--------|---------------------------------|---------------------------------|
| a. | [ama ₁ nta] _i | [amba ₁ nta] _j | | * | * |
| b. | [ama ₁ nta] _{i,j} | | *! | | |

In the second type of system, where *MERGE is ranked between MINDIST N-NC: V-ORAL₂ and MINDIST N-NC: V-ORAL₃, NCD occurs in only those contexts where N-NC is less perceptible. This is the case in Ngaju Dayak, for example, where N-NC is neutralized given a following coda nasal (12a-b). In other contexts, N-NC is licit (12c-d).

- (12) Ngaju Dayak: NCD only when N₂ is a coda (data simplified from (4))

| | /mambando/ _i | /mamando/ _j | MD N-NC: V-ORAL ₂ | *MERGE | MD N-NC: V-ORAL ₃ |
|----|--|---------------------------------------|---------------------------------|--------|---------------------------------|
| a. | [mama ₁ ndo] _i | [mamba ₁ ndo] _j | *! | | * |
| b. | [mama ₁ ndo] _{i,j} | | | * | |
| | /manen _{en} / _i | /manden _{en} / _j | | | |
| c. | [mane ₂ nen] _i | [mande ₂ nen] _j | | | * |
| d. | [mane ₂ nen] _{i,j} | | | *! | |

Finally, systems where both MINDIST N-NC: V-ORAL_x constraints >> *MERGE are systems in which NCD occurs in all nasal contexts. Such a ranking characterizes languages like Luganda, where NCD occurs to repair any sequence in which NC is followed by onset or coda N (13).

- (13) Luganda: NCD when N₂ is a coda or an onset (data simplified from (3))

| | /mumba/ _i | /mbumba/ _j | MD N-NC: V-ORAL ₂ | MD N-NC: V-ORAL ₃ | *MERGE |
|----|--------------------------------------|-------------------------------------|---------------------------------|---------------------------------|--------|
| a. | [mu ₁ mba] _i | [mbu ₁ mba] _j | *! | * | * |
| b. | [mu ₁ mba] _{i,j} | | | | * |
| | /nimi/ _i | /ndimi/ _j | | | |
| c. | [ni ₂ mi] _i | [ndi ₂ mi] _j | | *! | * |
| d. | [ni ₂ mi] _{i,j} | | | | * |

The constraints introduced in (8–10) cannot derive systems in which NCD occurs only preceding onset nasals, because MINDIST constraints are unable to penalize a more distinct contrast to the exclusion of a less distinct one. For example, there is no possible MINDIST N–NC: NC/_V-ORAL_x constraint that can penalize (12c), [mane₂ŋeni, mande₂ŋeni] to the exclusion of (12a), [mama₁ndo_i, mamba₁ndo_i]. Given this, the implication that repair of NC₁VNC₂ implies repair of NC₁VN₂V is derived. More broadly, if two contexts (CONT₁ and CONT₂) differ in that some contrast *x–y* is better-cued in CONT₁ than it is in CONT₂, then the presence of *x–y* in CONT₂ (where it is less well-cued) asymmetrically implies its presence in CONT₁ (where it is better-cued) (see Steriade 1997).⁵

This analysis predicts that all languages with NCD exhibit patterns of nasal coarticulation in line with the cross-linguistically common patterns described above. More specifically, it predicts that in languages that ban NC₁VNC₂ but not NC₁VN₂V, the intermediate vowel in NC₁VNC₂ is more nasalized than that of NC₁VN₂V. This larger point has not been established, and doing so would require large amounts of high-quality acoustic data from each language under consideration. Such data is not available at present, but for fragmented evidence that some of the surveyed languages exhibit regressive nasal coarticulation, see: Whitehead 1964:5 for Bobangi; Wambui 2014 for Gikuyu; Ennever 2014:97 for Gurindji; Herbert 1977:114 for Luganda (though cf. Maddieson & Ladefoged 1993:277–8); Essono 2000:30 for Yaunde; and below on Yindjibarndi.

2.3 Preconsonantal vs. word-final nasals

If the difference between the amounts of coarticulation induced by onset and coda nasals is responsible for the generalization in (3–5), we might expect – all else being equal – that languages that allow NC₁VN₂V but ban NC₁VNC₂ should also ban NC₁VN₂ when N₂ is word-final. To test this prediction, I focused on the 10 surveyed languages that allow NC₁VN₂V, ban NC₁VNC₂, and permit word-final nasals. Of these, 6 ban NC₁VN₂; 4 allow it.

- (14) Restrictions on NC₁VNC₂ and NC₁VN₂, but not NC₁VN₂V
(6 languages, including Mudbura; McConvell 1988)
- a. *NC₁VNC₂: /waŋa+ŋt+[a/ → [waŋa-t-[a], *[waŋa-ŋt-[a] ‘he might/should get it’
 - b. *NC₁VN₂: /ja+nta+ŋ/ → [ja-na-ŋ], *[ja-nta-ŋ] ‘come here!’
 - c. NC₁VN₂: /ŋumpina/ → [ŋumpina], *[ŋumpita] ‘man’
- (15) Restrictions on NC₁VNC₂, but not NC₁VN₂ or NC₁VN₂V
(4 languages, including Yindjibarndi; Wordick 1982)
- a. *NC₁VNC₂: /munti+mpa/ → [munti-pa], *[munti-mpa] ‘really (topic.)’
 - b. NC₁VN₂: /kaŋkan/ → [kaŋkan], *[kaŋkat] ‘vee’
 - c. NC₁VN₂V: /kantu+ŋarra/ → [kantu-ŋarra], *[kantu-karra] ‘low-lying cloud...’

There are independent factors in play for each of the languages in (15). In Yaunde, it is unclear what the scope of NCD is. Meeussen (p. 28) provides an example of NCD applying across an imperative suffix boundary (/lumbu+ŋgu/ → [lumu-ŋgu] ‘bow, stoop’), but words like [ndamba] ‘rubber’ (p. 48), [ndama] ‘to be wide open’ (p. 45), and [mboŋ] ‘palm flower’ (p. 29) in Essono’s (2000) grammar suggest that NCD is not fully general. The most straightforward interpretation of

⁵ Note that this analysis also predicts that if we were to find a language that forbids NCs from preceding C, it should also forbid them from preceding N. Languages that ban NCs preceding C were not found in the survey.

this discrepancy is that NCD only occurs across certain morphological boundaries; in this case it is not surprising that monomorphemic words like [mbonj] exist. The situation in Gooniyandi (McGregor 1990) is similar. NCD occurs in forms suffixed by the ergative postposition [-ŋga] (/go:ŋbo:ŋga/ → [go:ŋbo:-ga] ‘by the woman’, McGregor p. 98), but generally not within morphemes ([lɪnbəŋdi] ‘a type of edible leaf’) or across other morpheme boundaries.⁶ It is possible to explain forms like [bɪnbɪn] ‘crimson chat’ (p. 61) by appealing to NCD’s morphologically specific nature. In Yindjibarndi, the situation is somewhat different: NCD is general throughout the language but restricted to certain kinds of NC₁VNC₂ sequences (see Section 2.4). NCD occurs when NC₂ is labial (as in (8a)) or velar (/wuntu+ŋka/ → [wuntu-wa] ‘river (loc.)’, Wordick p. 33), but not otherwise (/kaŋkan+la/ → [kaŋkan-ta] ‘in the fork’, p. 35). All else being equal, we might expect NC₁VN₂ to be forbidden with labial or velar N₂, but permitted otherwise (as in (8b)). Yindjibarndi does not allow labial or velar nasals in word-final position (Wordick p. 13), so the second half of this prediction cannot be tested.

Finally, in Bilinara, NCD applies only when NC₂ is homorganic, with resulting deletion of N₂ (/ɲunu+ɲpa+ŋku+lu/ → [ɲunu-ɲpa-ku-lu], you-DAT-LINK-2s.o.-3p.s., McConvell 1988:152). In forms like [ɲumpin] ‘man’ (p. 149), the failure of [n] to denasalize (as in Gurindji [ɲumpit]) or delete (as in clusters) can be accounted for by adding several faithfulness constraints to the analysis proposed in Section 2.1.⁷ First, NCD never results in denasalization, which is consistent with the claim that IO-IDENT[nasal] (16) dominates MINDIST N–NC: V-ORAL₂. Second, assuming that in a homorganic NC the place feature is shared between N and C, deletion of /ŋ/ from an input like /ɲunu+ɲpa+ŋku+lu/ does not result in the loss of the consonant’s [velar] feature, because that place feature is still linked to the output [k]. By contrast, the /n/ of /ɲumpin/ has no following consonant to share its place feature with, so deletion of /n/ would result in the loss of its [coronal] feature as well. We can account for the failure of the final [n] in [ɲumpin] to delete by claiming that MAX[place] (17) dominates MINDIST N–NC: V-ORAL₂ as well.

- (16) IO-IDENT[nasal]:
Assign one * for each input [αnasal] segment whose output correspondent is [-αnasal].
- (17) MAX[place]:
Assign one * for each input place feature that lacks an output correspondent.

As shown in (18–19), the ranking IO-IDENT[nasal], MAX[place], MINDIST N–NC: V-ORAL₂ >> *MERGE predicts that NCD should occur in NC₁VNC₂ but not NC₁VN₂. To be concrete, I assume that deletion of N₂ violates MAX-SEG (= a * for each input segment without an output correspondent), but it would also be possible in (18) to view the loss of /ŋ/ as a consequence of fusion with /k/, which would violate UNIFORMITY (see Pater 1999). The identity of this faithfulness constraint is not crucial. (The ORAL_x values in (18–19) are as assumed in Sec. 2.2. The tableaux below consider four-membered candidates so that *MERGE can be evaluated; the repair to insufficiently distinct N–NC₁ in Bilinara involves removal of the nasalization in the intervening vowel through neutralization of C–NC₂.)

⁶ In Gooniyandi, homorganic and non-homorganic NCs cannot co-occur within morphemes. This restriction is part of a larger ban on cluster co-occurrence, which also target stop-stop clusters, nasal-nasal clusters, and liquid-initial clusters.

⁷ It is an open question whether or not standard-issue Faithfulness constraints should coexist with *MERGE in Dispersion Theoretic analyses, but for expositional simplicity I assume this is possible.

- (18) Bilinara: N₂ is deleted in NC₁VNC₂ (segments hosting the [velar] feature are underlined)

| | /...npa <u>ŋ</u> ku.../ _i | /...npa <u>ŋ</u> ku.../ _j | IO-IDENT [nasal] | MAX [place] | MD N–NC: V-ORAL ₂ | *MERGE |
|----|---|---|---------------------|----------------|---------------------------------|--------|
| | /...npa <u>k</u> ku.../ _k | /...npa <u>k</u> ku.../ _l | | | | |
| a. | [...npa ₁ <u>ŋ</u> ku...] _i | [...npa ₁ <u>ŋ</u> ku...] _j | | | *! | |
| | [...npa ₃ <u>k</u> ku...] _k | [...npa ₃ <u>k</u> ku...] _l | | | | |
| b. | [...npa ₃ <u>k</u> ku...] _i | [...npa ₁ <u>ŋ</u> ku...] _j | *! | | | |
| | [...npa ₃ <u>k</u> ku...] _k | [...npa ₃ <u>k</u> ku...] _l | | | | |
| c. | [...npa ₃ <u>k</u> ku...] _{i,k} | [...npa ₁ <u>ŋ</u> ku...] _j | | | | * |
| | [...npa ₃ <u>k</u> ku...] _l | [...npa ₃ <u>k</u> ku...] _l | | | | |

- (19) Bilinara: N₂ remains in NC₁VN₂ (segments hosting the [coronal] feature are underlined)

| | /ŋump <u>i</u> / _i /ŋump <u>i</u> / _k | /ŋum <u>i</u> / _j /ŋup <u>i</u> / _l | IO-IDENT [nasal] | MAX [place] | MD N–NC: V-ORAL ₂ | *MERGE |
|------|--|--|---------------------|----------------|---------------------------------|--------|
| ☞ a. | [ŋump <u>i</u> ₁ <u>n</u>] _i [ŋump <u>i</u> ₃ <u>t</u>] _k | [ŋum <u>i</u> ₁ <u>n</u>] _j [ŋup <u>i</u> ₁ <u>n</u>] _l | | | * | |
| b. | [ŋump <u>i</u> ₃ <u>t</u>] _i [ŋump <u>i</u> ₃] _k | [ŋum <u>i</u> ₁ <u>n</u>] _j [ŋup <u>i</u> ₁ <u>n</u>] _l | *! | | | |
| c. | [ŋump <u>i</u> ₃] _{i,k} [ŋup <u>i</u> ₁ <u>n</u>] _l | [ŋum <u>i</u> ₁ <u>n</u>] _j [ŋup <u>i</u> ₁ <u>n</u>] _l | | *! | | * |

In sum, the data are consistent with an analysis where MINDIST constraints penalize NC₁VNC₂ and NC₁VN₂ equally. The four cases in which only NC₁VNC₂ is dispreferred are plausibly analyzed by reference to morphological factors or high-ranked faithfulness constraints.

2.4 Further asymmetries and evidence from Yindjibarndi

The hypothesis introduced above has the potential to help us understand further language-specific restrictions on NCD. In Mori Bawah, for example, NCD only occurs when NC₂ is voiceless (20). In Yindjibarndi, NCD only occurs when NC₂ is labial or velar (21).⁸

- (20) NCD in Mori Bawah (data from Blust 2012:369)

- a. Applies when NC₂ is voiceless
 - i. /moN+soŋka/ → [mo-soŋka] ‘arrange’
 - ii. /moN+tampele/ → [mo-tampele] ‘hit, smack’
- b. Does not apply when NC₂ is voiced
 - i. /moN+sombu/ → [mon-sombu] ‘connect, join’
 - ii. /moN+tonda/ → [mon-tonda] ‘follow’

- (21) NCD in Yindjibarndi (data from Wordick 1982:33-35)

- a. Applies when NC₂ is labial or velar
 - i. /wuntu+ŋka/ → [wuntu-wa] ‘river (loc.)’
 - ii. /munti+mpa/ → [munti-pa] ‘really (top.)’
- b. Does not apply otherwise
 - i. /kaŋkan+la/ → [kaŋkan-ta] ‘in the fork’
 - ii. /kaŋkan+karra/ → [kaŋkan-karra] ‘forked’

⁸ NCD applies near-exceptionlessly both across and within morphemes in Yindjibarndi. The only apparent exception is *Yantimpurrwa*, a proper name (Wordick 1982:35).

The hypothesis above allows us to predict that vowels in Mori Bawah should be more nasalized preceding voiceless NCs than preceding onset Ns or voiced NCs, as is true for English (Cohn 1990, Beddor 2009). It also allows us to predict that vowels in Yindjibarndi should be more nasalized preceding [mp] and [ŋk] (or “peripheral” NCs, to use Australianist terminology) than preceding non-peripheral (coronal) NCs, heterorganic NCs, or onset nasals. Below I verify that the prediction regarding Yindjibarndi is correct, and leave further investigation of Mori Bawah to future work.

To quantify patterns of nasal coarticulation in Yindjibarndi, I selected 36 words from the UCLA Phonetics Archive where a primary-stressed initial /a/ is followed by an oral stop, an onset N, a peripheral NC, or a non-peripheral cluster. Each word was repeated several times, for a total of 100 tokens. Tokens are divided in (22) into four categories: those with a following oral stop (22a), an onset nasal (22b), a peripheral cluster (22c; subdivided into labial and velar), or a non-peripheral cluster (22d). These words are limited to those in which a nasal appears only post-stress; words like *manthu* were not considered to avoid potential confounding effects of perseveratory nasalization. All tokens are produced by a single male speaker.

(22) Yindjibarndi tokens by following context (vowel of interest underlined)

| Following context | Number | Examples |
|-------------------------------|--------|---------------------------------------|
| a. Oral stop | 21 | <i>ba<u>d</u>jarri, ka<u>r</u>daa</i> |
| b. Onset nasal | 34 | <i>ka<u>m</u>u, ka<u>n</u>a</i> |
| c. Peripheral cluster: Labial | 9 | <i>tha<u>m</u>bi, ja<u>m</u>bu</i> |
| Peripheral cluster: Velar | 3 | <i>ka<u>ŋ</u>kaj</i> |
| d. Non-peripheral cluster | 39 | <i>ja<u>n</u>da, ba<u>r</u>nnga</i> |

The measure chosen to quantify acoustic nasality was compensated A1-P0, as measured by the Nasality Automeasure Script Package (Styler & Scarborough 2015; see Chen 1995, 1997 on A1-P0). A1-P0 is a measure of the amplitude of the first oral formant (A1) relative to the amplitude of a low-frequency nasal peak (P0). A1-P0 is “robust, well-studied, and well-correlated with nasality” and claimed to be “the best single-number measure of nasality currently available” (Styler & Scarborough 2015). The vowels considered here were limited to /a/ because A1-P0 is mostly useful for non-high vowels, and the only non-high vowel in Yindjibarndi is /a/. Measurements were taken at five equally-spaced timepoints throughout each vowel. Timepoints 1 and 5 were offset 5ms from the beginning and end of the vowel, to avoid influence from neighboring consonants. Of 500 possible measurements, the script took 496.⁹

Results are in Figure 1 (graphs in this article are created with R’s ggplot2 package, Wickham 2009). The y axis reflects the average compensated A1-P0; lower A1-P0 measures are correlated with more nasalization. The contexts classified as “peripheral” are in black, and others are in gray; in the legend for “Following context”, the top-to-bottom order of the five contexts reflects the relative A1-P0 at Timepoint 5, from highest to lowest.

⁹ The four failed measurements returned a “Crash-PulseBegin” error message, indicating that Praat was not able to generate needed values. (These four were *banyi, kamayi, karndara, and badjarri at Timepoint 1.)*

Figure 1: Compensated A1-P0 in Yindjibarndi vowels by following context

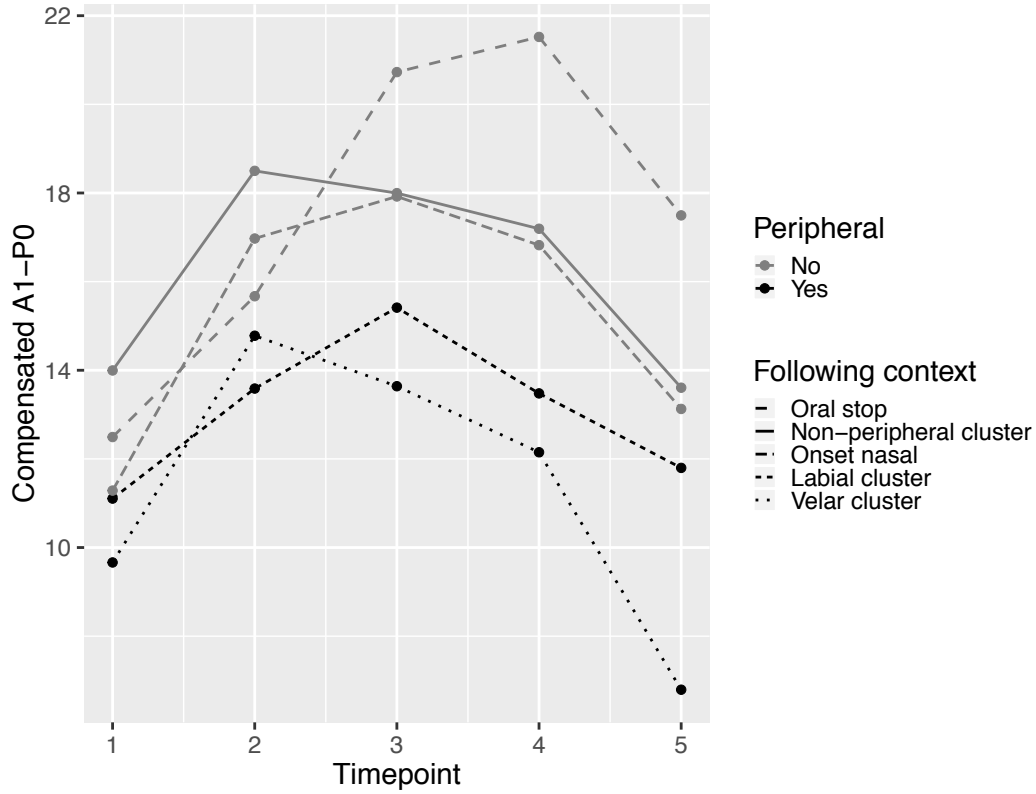


Figure 1 shows that the average A1-P0 of the vowels preceding peripheral NCs is lower at each timepoint than is the average A1-P0 of the other vowels. To determine if this difference between contexts was meaningful, a mixed effects linear regression was fit to the data. The dependent variable was compensated A1-P0; fixed effects included treatment-coded predictors for the type of following context (reference level = "non-peripheral") and the timepoint (reference level = 1). A random intercept for token was also included.¹⁰

(23) Results of statistical analysis for Yindjibarndi nasalization

| Factor | Coefficient | <i>t</i> value | Significant? |
|--------------------|-------------|----------------|--------------------|
| a. Peripheral: Yes | -3.44 | -2.84 | Yes ($p < .01$) |
| b. Timepoint: 2 | 4.42 | 6.52 | Yes ($p < .001$) |
| c. Timepoint: 3 | 5.67 | 8.36 | Yes ($p < .01$) |
| d. Timepoint: 4 | 5.00 | 7.37 | Yes ($p < .001$) |
| e. Timepoint: 5 | 1.41 | 2.07 | Yes ($p < .001$) |

The effects in (23b-e) indicate that the average A1-P0 depends on Timepoint; this is unsurprising given the variation observable in Figure 1. The result of interest is the effect of Peripheral (23a): the negative coefficient indicates that vowels followed by a peripheral NC are associated with lower

¹⁰ A series of likelihood ratio tests indicate that (i) a model including Peripheral is a better fit to the data than one that does not ($\chi^2(1) = 7.54, p < .01$), (ii) a model including Timepoint is a better fit than one that does not ($\chi^2(1) = 95.42, p < .001$), and (iii) including an interaction between Peripheral and Timepoint does not improve fit ($\chi^2(1) = 2.11, p > .1$).

A1-P0 values. Assuming that this speaker is representative of the larger population, these results are consistent with the hypothesis that NCD tracks acoustics of nasalization. In Yindjibarndi, the context in which NCD occurs is the context in which the post-NC₁ vowel would be most nasalized.

We can analyze the pattern in Yindjibarndi as follows. There is evidence for two ORAL_x categories: one for vowels that precede a peripheral NC (ORAL₁), and one for vowels preceding another segment or sequence type (ORAL₂). By ranking MINDIST N–NC: V-ORAL₂ above *MERGE, we can derive the generalization that NCD occurs before peripheral NCs in Yindjibarndi (24a-b) but not elsewhere (24c-d). (The tableau below again considers four-membered candidates so that *MERGE can be evaluated; as in Bilinara, NCD here involves neutralization of the C-NC₂ contrast.)

(24) Yindjibarndi: NCD when NC₂ is peripheral (V = ORAL₁)

| | /muntimpa/i /muntipa/k | /munimpa/j /munipa/ɭ | MD N–NC: V-ORAL ₂ | *MERGE |
|------|---|---|---------------------------------|--------|
| a. | [munti ₁ mpa] _i [munti ₂ pa] _k | [muni ₁ mpa] _j [muni ₂ pa] _ɭ | *! | |
| ☞ b. | [munti ₂ pa] _{i,k} | [muni ₁ mpa] _j [muni ₂ pa] _ɭ | | * |
| | /kaŋkanta/i /kaŋkata/k | /kaŋanta/j /kaŋata/ɭ | | |
| ☞ c. | [kaŋka ₂ nta] _i [kaŋka ₂ ta] _k | [kaŋa ₂ nta] _j [kaŋa ₂ ta] _ɭ | | |
| d. | [kaŋka ₂ ta] _{i,j} | [kaŋa ₂ nta] _j [kaŋa ₂ ta] _ɭ | | *! |

What is necessary to confirm now is that perception of an N–NC contrast is influenced by the amount of nasalization in the following V, as measured in this way. For this see Section 4.

3 The left-hand context: generalizations and analysis

The identity of the right-hand context plays a role in determining whether or not NCD applies, but the identity of the left-hand context (NC₁, in NC₁VNC₂) can matter as well. I discuss the roles of stop voicing (Section 3.1) and place of articulation (Section 3.2), and propose an analysis under which these generalizations are also linked to acoustic and perceptual factors: NCD becomes more likely as the salience of NC₁'s oral release decreases (Section 3.3).

3.1 Stop voicing

A consistent generalization throughout the typology of NCD is that it rarely targets NC₁VNC₂ when NC₁ is voiceless. In fact, the only language surveyed that exhibits NCD with voiceless NC₁ is Mori Bawah (for illustrative data see (20)). (While NCs in languages like Gurindji and Yindjibarndi are often transcribed with graphemes indicating voicelessness, like <p> or <k>, voicing in these languages is non-contrastive and post-N stops are generally voiced.)

Why does NCD prefer to target voiced NC₁? Herbert (1977:365) attributes the asymmetry to the observation that “in a post-nasal environment, the voiced stops evidence the most reduction and are therefore the most susceptible to nasalization...voiceless stops and fricatives are more

distinctive in this environment.” Building on this observation, I hypothesize that the relevant factor here has to do with the salience of the release: the longer the release of NC₁, the less likely NCD is to occur. The idea is that a longer oral release in NC enhances the internal cues to the N–NC contrast (see Steriade 1997 on internal vs. external cues), and renders it less dependent on its external cues, like the identity of the following vowel. For experimental evidence that the duration of NC’s oral component leads to increasingly accurate identification rates, see Beddor & Onsuwan (2003); for experimental evidence consistent with the present hypothesis see Section 4.

If this hypothesis is correct, the release phase of voiceless NCs must be longer than the release phase of voiced NCs in all languages where NCD targets voiced but not voiceless NCs. While this hypothesis has not been verified for all surveyed languages, the asymmetry has been documented generally (Maddieson & Ladefoged 1993 for Sukuma; Ladefoged & Maddieson 1996 for Bura; Riehl 2008 for Tamambo, Manado Malay, and Pamona; Coetzee & Pretorius 2010 for Tswana; Beguš & Nazarov 2017 for Tarma Quechua; Cho & Ladefoged 1999 on the more general asymmetry in release salience between voiced and voiceless stops; *a.o.*).

The prediction of the analysis investigated here is that if NCD occurs to avoid relatively more distinct N–NC₁ contrasts, it should also occur to avoid less distinct N–NC₁ contrasts. Therefore, if a language exhibits NCD when NC₁ is voiceless (and more easily distinguished from N), it should exhibit NCD when NC₁ is voiced (and less easily distinguished from N). As noted above, the only language in which NCD applies when NC₁ is voiceless is Mori Bawah, and in this language there are independent reasons why the prediction cannot be tested. NCD is attested most readily in Mori Bawah in forms prefixed with /moN-/ , but the nasal of this prefix only surfaces when the root begins with a voiceless stop (25).¹¹

(25) Effects of /moN-/ prefixation in Mori Bawah (data from Blust 2012:368)

- a. Stem begins with a voiceless stop: nasal place-assimilates
 - i. /moN+paho/ → [mom-paho] ‘plant’
 - ii. /moN+tunu/ → [mon-tunu] ‘roast, grill’
- b. Stem begins with any other segment: nasal deletes
 - i. /moN+basa/ → [mo-basa] ‘read’
 - ii. /moN+dagai/ → [mo-dagai] ‘guard’
 - iii. /moN+maru/ → [mo-maru] ‘climb’
 - iv. /moN+lulu/ → [mo-lulu] ‘chase’
 - v. /moN+aha/ → [mo-ʔaha] ‘whet, sharpen’

NCD is only observable when NC₁ is voiceless; these are the only kind of NC₁VNC₂ sequences that can arise in the relevant context. This renders the prediction that all NC₁VNC₂ sequences should undergo NCD regardless of NC₁’s voicing untestable, given the attested typology.

3.2 Place of articulation and evidence from Ngaju Dayak

If NCD is influenced by the duration of NC₁’s oral release, factors that influence release duration should influence NCD. One such factor is place of articulation, which is known to underlie variations in voice onset time (VOT). For example: Cho & Ladefoged (1999) find that stop VOT

¹¹ Note that the Mori Bawah data appear to provide a counterexample to Pater’s 1999 claim that voiceless NCs are universally marked relative to voiced NCs.

tends to increase as the closure moves further back into the vocal tract, though there is variation across languages (their p. 219). Given this, it is impossible to make universal predictions regarding correlations between NCD and NC₁'s place of articulation, but we can predict that the two should correlate similarly with release duration: the longer NC₁'s release, the less likely NCD should be.

Cases of NCD that track NC₁'s place of articulation are uncommon; the only well-documented case I am aware of comes from Ngaju Dayak. Table 1 (adapted from Blust 2012:373, with data from Hardeland 1859) summarizes the rate of NCD according to NC₁'s place of articulation and whether or not NCD is expected. Across categories, the difference between the rates of NCD according to NC₁'s following context (NC vs. C) demonstrate that NCD is conditioned by the presence of a following NC. Within the class of forms where NCD is expected, it applies most frequently when NC₁ is labial, less so when NC₁ is velar or alveolar, and least when NC₁ is palatal.

Table 1: NCD in Ngaju Dayak

| NCD expected? | NC ₁ PoA | NCD applies? | | Variable |
|---|-----------------------------|----------------------------|-----------------------------|----------------|
| | | Yes | No | |
| Yes (NC ₁ VNC ₂) No (NC ₁ VC ₂ V) | Bilabial (mb ₁) | 93% (63/67) 6% (9/159) | 3% (2/67) 94% (150/159) | 3% (2/67) – |
| Yes (NC ₁ VNC ₂) No (NC ₁ VC ₂ V) | Alveolar (nd ₁) | 29% (2/7) 4% (3/75) | 29% (2/7) 96% (72/75) | 43% (3/7) – |
| Yes (NC ₁ VNC ₂) No (NC ₁ VC ₂ V) | Palatal (ɲdʒ ₁) | 15% (2/13) – | 85% (11/13) 100% (89/89) | – – |
| Yes (NC ₁ VNC ₂) No (NC ₁ VC ₂ V) | Velar (ŋg ₁) | 64% (16/25) 9% (10/114) | 36% (9/25) 91% (104/114) | – – |

To determine which place-based differences are meaningful, a logistic regression was fit (using R's glm function) to the forms in Table 1 in which NCD is expected to apply. The dependent variable was whether or not NCD applies; the independent variable was NC₁'s place of articulation. Variable cases were counted as NCD undergoers and non-undergoers. Pairwise differences in (26) were assessed with Tukey's HSD post-hoc tests, using the glht function of R's multcomp package (Hothorn et al. 2008). A positive coefficient means that the second member of the comparison is associated with a higher rate of NCD, while a negative coefficient means that the first is.

(26) Pairwise comparisons for Ngaju Dayak dictionary data

| Comparison | Coefficient | z value | Significant? |
|----------------------|-------------|---------|------------------------|
| a. Bilabial-Alveolar | 0.44 | 3.75 | Yes ($p < .01$) |
| b. Bilabial-Palatal | 0.79 | 7.48 | Yes ($p < .001$) |
| c. Bilabial-Velar | 0.30 | 3.71 | Yes ($p < .01$) |
| d. Alveolar-Palatal | 0.35 | 2.36 | Trending ($p = .08$) |
| e. Alveolar-Velar | -0.14 | 1.07 | No ($p = .70$) |
| f. Palatal-Velar | -0.49 | 4.08 | Yes ($p < .001$) |

The rate of application for [mb]₁ is lower than the mean rate of application for each of the other categories, and the rate of application for [ŋg]₁ (and likely [nd]₁) is lower than the rate of application for [ɲdʒ]₁. Taking into account the hypothesis of this section, and given these results, we can make predictions about the phonetics of Ngaju Dayak NCs: the average release duration of [mb] should be shorter than that of other categories, and the average release duration of [ŋg] (and likely [nd])

should be shorter than that of [ndʒ]. (The data do not allow us to make any predictions about the relationship between [nd] and [ŋg].)¹²

To test these predictions, data on the duration of oral NC releases was collected from recordings of the New Testament in Ngaju Dayak, available from Bible.is. 446 recordings of prevocalic [mb], [nd], [ndʒ], or [ŋg] were obtained from Matthew and John. For each cluster, the duration of the oral release was measured from the beginning of the stop burst until the onset of the vowel's periodic voicing. Speaker identity was not controlled for, though all speakers sounded male and spoke at similar rates. In 149/446 recordings there was no observable stop burst, but the available Ngaju recordings are not studio-quality and are often accompanied by background noise. Because of this, it is possible that the stop release was just obscured. Due to this complication, only the tokens with clear stop releases were measured. Spectrograms of two tokens (one with a clear and observable stop release, and one without) are in Figure 2.¹³

Figure 2: measuring oral stop releases in Ngaju Dayak

Figure 2a: observable stop release (boxed) in [handiai] (Matthew 1)

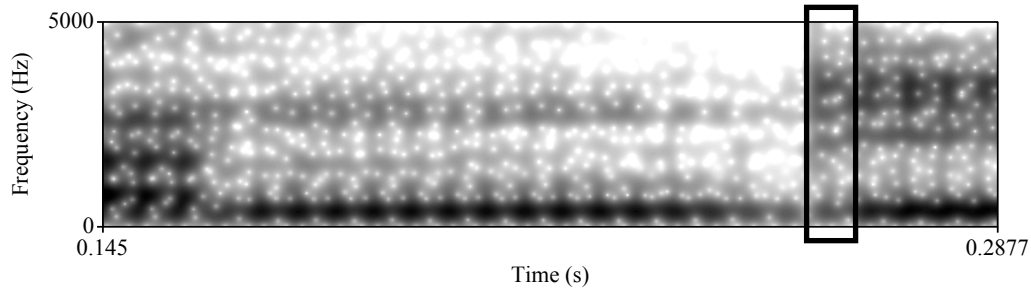
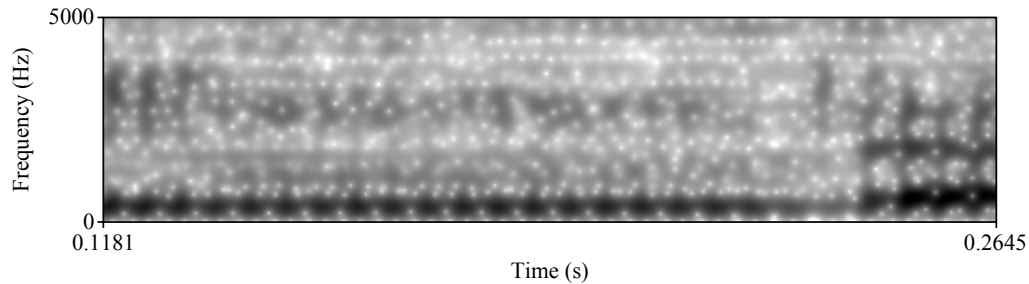


Figure 2b: no observable stop release in [hindai] (Matthew 1)

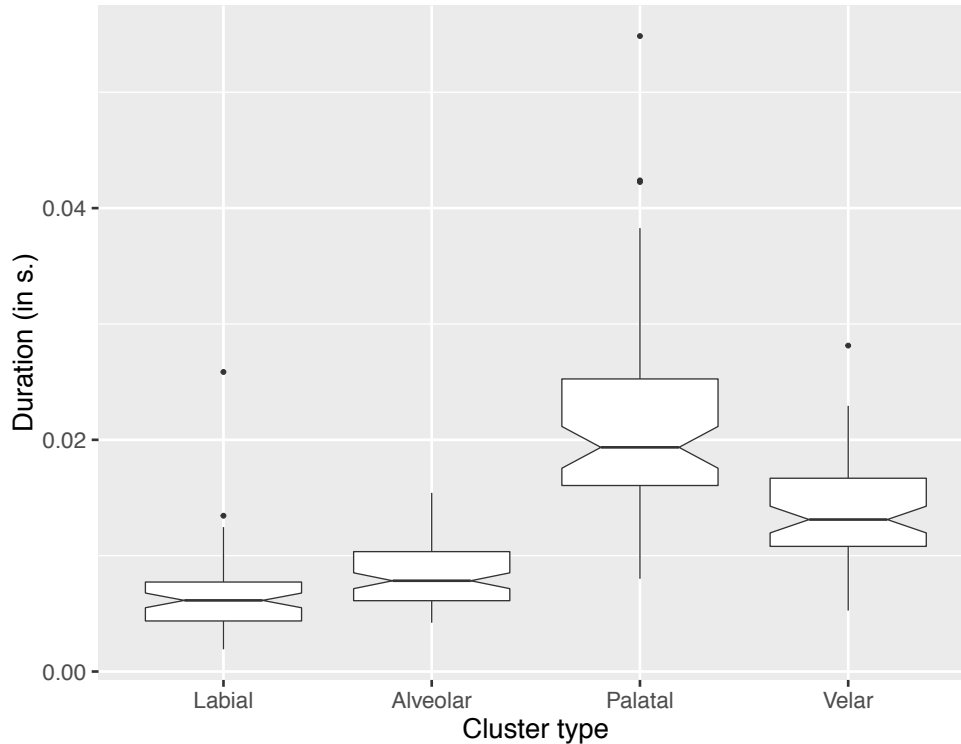


In total, 70 tokens of released [mb], 96 tokens of released [nd], and 65 tokens each of released [ndʒ] and released [ŋg] were obtained. Resulting measurements are summarized in Figure 3.

¹² There are also several languages which are claimed to only exhibit NCD with [ŋg]₁ (see the appendix). These claims are less well-documented (typically they are made in half a sentence by Meeussen 1963, with no supporting data), but could be understood in this same way if these languages the release of [ŋg] is shorter than the release of other voiced NCs. The acoustic data necessary to test this prediction is not available.

¹³ Of the 149 with no observable release, there were 66 [mb]s (48.5%), 49 [nd]s (33.8%), 7 [ndʒ]s (9.7%), and 27 [ŋg]s (29.9%). Likelihood of non-release is negatively correlated with release duration when released (see Fig. 3); conclusions drawn from this could be that shorter releases are more likely to be obscured or that they are more likely to be absent.

Figure 3: oral release duration in Ngaju Dayak by place of articulation



These results confirm that asymmetries in release duration are the inverse of asymmetries in NCD frequency. [mb] has the shortest release; when NC₁ in NC₁VNC₂ is [mb], NCD is most frequent. [ndʒ] has the longest release; when NC₁ in NC₁VNC₂ is [ndʒ], NCD is least frequent. Pairwise comparisons from a linear model, obtained again with the `glht` function of R's `multcomp` package, are in (27); all comparisons except labial-alveolar are significant.

(27) Pairwise comparisons for Ngaju Dayak release data

| Comparison | Coefficient | <i>t</i> value | Significant? |
|----------------------|-------------|----------------|--------------------|
| a. Bilabial-Alveolar | 0.001 | 2.07 | No ($p = .17$) |
| b. Bilabial-Palatal | 0.015 | 16.76 | Yes ($p < .001$) |
| c. Bilabial-Velar | 0.007 | 8.16 | Yes ($p < .001$) |
| d. Alveolar-Palatal | 0.013 | 15.95 | Yes ($p < .001$) |
| e. Alveolar-Velar | 0.006 | 6.73 | Yes ($p < .001$) |
| f. Palatal-Velar | -0.008 | -8.44 | Yes ($p < .001$) |

Discrepancies between the dictionary and acoustic data involve the alveolars: the bilabial-alveolar comparison is significant in the dictionary data (26a) but not the acoustic data (27a), and the alveolar-velar comparison is significant in the acoustic data (27e) but not the dictionary data (26e). Given the low number of alveolar tokens in the dictionary ($n=7$), it is likely that these discrepancies reflect limitations of the data. The results of this small study thus indicate a plausible correlation in Ngaju Dayak between the rate of NCD and the average duration of NC₁'s oral release.

3.3 Analysis

The evidence in this section suggests that NC-internal properties play an independent role in NCD. I formalize this by introducing MINDIST constraints that require NC to have an oral release of at least a certain duration to be sufficiently distinct from N. Here too I assume that learners are capable of grouping NCs into separate categories (REL_x) according to the duration of their releases; the exact constitution of the categories depends on language-specific asymmetries in release duration. The fact that NCD only rarely targets NC_1VNC_2 when NC_1 is voiceless suggests that in most languages, NCs are divided into at least two categories: one for voiceless NCs (with longer releases), and another for voiced NCs (with shorter releases). In addition, the correlation between place of articulation and NCD in Ngaju Dayak suggests that these categories can be more fine-grained; it is useful in this case to assume that voiced NCs can be divided up as in (28).

- (28) REL scale for Ngaju Dayak (voiceless NCs not included)

| REL _x value | Ngaju Dayak referent |
|------------------------|----------------------|
| REL ₁ | [mb] |
| REL ₂ | [nd] |
| REL ₃ | [ŋg] |
| REL ₄ | [ndʒ] |

Given this scale, we can define three MINDIST constraints along the REL dimension: MINDIST N–NC: NC-REL₂, MINDIST N–NC: NC-REL₃, and MINDIST N–NC: NC-REL₄ (29–31).

- (29) MINDIST N–NC: NC-REL₂:
Assign one violation for each contrast between N and NC in which NC does not have an oral release that belongs to category of 2 or larger along the REL scale.
- (30) MINDIST N–NC: NC-REL₃:
Assign one violation for each contrast between N and NC in which NC does not have an oral release that belongs to category of 3 or larger along the REL scale.
- (31) MINDIST N–NC: NC-REL₄:
Assign one violation for each contrast between N and NC in which NC does not have an oral release that belongs to category of 4 or larger along the REL scale.

In Ngaju Dayak, the combined influences of the lefthand and righthand contexts can be modeled as additive interactions of MINDIST constraints along the REL and ORAL dimensions. Put slightly differently, the penalty assigned to a given N–NC contrast depends on two factors: the identity of the NC and the identity of the righthand context. To illustrate this explicitly, I fit a Maxent grammar to the Ngaju Dayak count data (Table 1) using five constraints: the MINDIST constraints in (29–31), *MERGE (10), and MINDIST N–NC: V-ORAL₂ (8); I assume that ORAL=1 for vowels preceding NC and that ORAL=2 for vowels preceding C. The weights discovered by the Maxent grammar tool (Wilson & George 2008) follow.

(32) Weights for Ngaju Dayak count data

| Constraint | Weight |
|-----------------------------------|--------|
| *MERGE | 6.07 |
| MINDIST N–NC: V-ORAL ₂ | 4.24 |
| MINDIST N–NC: NC-REL ₄ | 2.92 |
| MINDIST N–NC: NC-REL ₂ | 0.82 |
| MINDIST N–NC: NC-REL ₃ | 0 |

These constraints interact to approximate the frequency counts. In the case of labials, for example, the combined weights of the MINDIST constraints along the ORAL and REL dimensions result in an overwhelming likelihood that, in the NC₁VNC₂ context, [m-mb] neutralizes. Numeric subscripts indicate a value along the ORAL or REL scale; alphabetical subscripts indicate correspondence.

(33) Neutralization of [m-mb] in VNC context predicted to be frequent

| <i>weight:</i> | | 6.07 | 4.24 | 2.92 | 0.82 | | |
|----------------|--|--------|--------------------------------------|--------------------------------------|--------------------------------------|---------|-------|
| | | *MERGE | MINDIST N–NC: V-ORAL ₂ | MINDIST N–NC: NC-REL ₄ | MINDIST N–NC: NC-REL ₂ | | |
| | | | | | | Harmony | Prob. |
| | /mV ₁ NC/ _i /mb ₁ V ₁ NC/ _j | | | | | | |
| a. | /mV ₁ NC/ _i /mb ₁ V ₁ NC/ _j | | * | * | * | 7.98 | 13.0% |
| b. | /mV ₁ NC/ _{i,j} | * | | | | 6.07 | 87.0% |

In the NC₁VC₂ context, MINDIST N–NC: V-ORAL₂ is satisfied, so the candidate with an [m-mb] contrast has a lower harmony score. As shown below, this results in a lower (though correctly non-zero) probability that neutralization occurs in this context.

(34) Neutralization of [m-mb] in VC context predicted to be infrequent

| <i>weight:</i> | | 6.07 | 4.24 | 2.92 | 0.82 | | |
|----------------|--|--------|--|--------------------------------------|--------------------------------------|---------|-------|
| | | *MERGE | MINDIST N–NC: NC/ V-ORAL ₂ | MINDIST N–NC: NC-REL ₄ | MINDIST N–NC: NC-REL ₂ | | |
| | | | | | | Harmony | Prob. |
| | /mV ₂ C/ _i /mb ₁ V ₂ C/ _j | | | | | | |
| a. | /mV ₂ C/ _i /mb ₁ V ₂ C/ _j | | | * | * | 3.74 | 91.2% |
| b. | /mV ₂ C/ _{i,j} | * | | | | 6.07 | 8.8% |

Overall results are summarized in Table 2. The model captures the fact that NCD occurs more frequently with following NC₂ than with following C₂. It also captures the fact that the rate of N–NC₁ neutralization tracks the average duration of NC₁'s oral release: palatal contrasts, for example, are less likely to undergo neutralization than are labial contrasts.

Table 2: results of maxent analysis for Ngaju Dayak count data

| Input | Outputs | Observed freq. | Predicted freq. | Difference |
|-------------|-------------|-----------------|-----------------|-------------------|
| mVNC–mbVNC | mVNC–mbVNC | 5.8% (4/69) | 13.0% (9/69) | +7.2% (5) |
| | mVNC | 94.2% (65/69) | 87.0% (60/69) | -7.2% (5) |
| mVCV–mbVCV | mVCV–mbVCV | 94.3% (150/159) | 91.2% (145/159) | -3.1% (5) |
| | mVCV | 5.7% (9/159) | 8.8% (14/159) | +3.1% (5) |
| nVNC–ndVNC | nVNC–ndVNC | 50.0% (5/10) | 25.2% (3/10) | -24.8% (2) |
| | nVNC | 50.0% (5/10) | 74.8% (7/10) | +24.8% (2) |
| nVCV–ndVCV | nVCV–ndVCV | 96.2% (75/78) | 96.0% (75/78) | -0.2% (0) |
| | nVCV | 3.8% (3/78) | 4.1% (3/78) | +0.2% (0) |
| ɲVNC–ɲdʒVNC | ɲVNC–ɲdʒVNC | 84.6% (11/13) | 86.2% (11/13) | +1.6% (0) |
| | ɲVNC | 15.4% (2/13) | 13.8% (2/13) | -1.6% (0) |
| ɲVCV–ɲdʒVCV | ɲVCV–ɲdʒVCV | 100.0% (89/89) | 99.8% (89/89) | -0.2% (0) |
| | ɲVCV | 0.0% (0/89) | 0.0% (0/89) | +0.2% (0) |
| ŋVNC–ŋgVNC | ŋVNC–ŋgVNC | 36.0% (9/25) | 25.2% (6/25) | -10.8% (3) |
| | ŋVNC | 64.0% (16/25) | 74.8% (19/25) | +10.8% (3) |
| ŋVCV–ŋgVCV | ŋVCV–ŋgVCV | 91.2% (104/114) | 95.9% (109/114) | +4.7% (5) |
| | ŋVCV | 8.8% (10/114) | 4.1% (5/114) | -4.7% (5) |

Decomposing MINDIST constraints on the N–NC contrast in this way predicts that NCs with longer releases should be generally preferred to those with shorter releases. While this prediction has not been investigated systematically, one potential piece of supporting evidence comes from nasal substitution in Tagalog (Zuraw 2010): among stems with initial voiced stops, substitution occurs more frequently with [N+b], less frequently with [N+d], and least frequently with [N+g]. If the phonetics of Tagalog voiced NCs mirror those of Ngaju Dayak, then Zuraw's (2010) finding is potentially explicable by the factors discussed here.

4 Experimental support

The proposed analysis for asymmetries in the NCD typology rests on two hypotheses regarding factors that make an NC more or less confusable with N, as summarized in (35).

- (35) Hypothesized perceptual factors
- The more nasalized a vowel following NC is, the more confusable NC is with N.
 - The shorter an NC's release, the more confusable the NC is with N.

Both of these hypotheses are consistent with what is currently known about the perception of NCs but are not supported in their specific form. Regarding (35a): Beddor & Onsuwan (2003) show that Ikalanga speakers' ability to correctly identify [mb] is negatively impacted by the presence of nasalization in a following vowel: speakers correctly identify [mb] most frequently when followed by an oral vowel, less frequently when followed by a vowel whose initial 36% is nasalized, even less frequently when followed by a vowel whose initial 68% is nasalized, and least frequently when followed by a fully nasal vowel. But showing that perception of NC depends on the duration of nasalization immediately following the release is quite different from showing that perception of NC depends on the amount of regressive coarticulatory nasalization from a following nasal consonant (which may not extend to the first NC's release), so Beddor & Onsuwan's (2003) results do not necessarily support (35a). Regarding (35b), Beddor & Onsuwan (2003) show that Ikalanga

speakers' ability to correctly identify [mb] is impacted by the duration of the oral closure and release burst: averaging across following contexts, correct identification rates of [mb] were highest when [mb]'s oral closure and release burst was 27 ms., lower at 18 ms., still lower at 9 ms., and lowest when it was absent. These results support the general idea that perception of NC is dependent on the salience of its oral release, but not the specific hypothesis in (35b).

What kind of evidence would allow us to be confident that (35a,b) – and the phonological analysis that appeals to them – are correct? The hypotheses in (35) assume that there are universal effects in speech perception, so it would be ideal to collect evidence from a wide variety of experimental tasks, with participants from a wide variety of language backgrounds. For example, a wide range of identification and discrimination tasks could be administered to four sets of participants, whose native languages differ in whether an N–NC contrast exists and whether or not NCD occurs. This would help us understand if (35a,b) are true of speakers from language backgrounds that vary in relevant ways. Converging results from multiple kinds of experimental task, and multiple sets of participants, would provide suggestive evidence that the hypotheses in (35) are on the right track. But even in this ideal case, the evidence would only be suggestive: the claims in (35) are universal, and it is an impractical aim to run multiple experiments with native speakers of each of the world's languages. It is also important to note that even if such work were possible, it would not tell us one way or the other if generalizations like (35a,b) form the substance of phonological grammars, nor would it shed light on how phonological generalizations are learned in first language acquisition, when sensitivity to phonetic detail is simultaneously acquired. Exactly how to probe these points is an open question not obviously answerable with current experimental methods in phonology. Thus, especially given the space limitations inherent to an article, my goal here is to provide enough experimental evidence to render (35a,b) and the analysis that rests on them plausible – not to argue that (35a,b) are universally true and a fundamental part of speakers' phonological grammars.

As such, this section reports the results of a single AX task designed to investigate the hypotheses as they are formulated in (35). An AX task was chosen because it allows for a direct test of the hypothesis that listeners' ability to discriminate N and NC depends on the contrast's segmental environment, and also because it is a standard task used to investigate hypotheses of this sort (e.g. Gallagher 2010). In what follows I show that the results are consistent with (35).

4.1 Materials

The stimuli for this experiment are trisyllabic nonce words produced by a male native speaker of Peruvian Spanish. Spanish was selected as the language for the stimuli because it is a language with different patterns of coarticulatory nasalization than are found in English. It is well-known that anticipatory nasal coarticulation in English is extensive, especially when the nasal consonant is pre-consonantal or word-final (see Cohn 1990), leading many authors to argue that nasalization in English is phonological, or "part of the programming instructions and not a function of physiological constraints of the vocal organs" (Solé 1992:30). In Spanish, by contrast, coarticulatory nasalization is less extensive, suggesting that nasalized vowels are "targeted as oral, and nasalization is the result of a physiological time constraint" (Solé 1992:38). Using productions from a Spanish speaker leads to a more conservative test of the hypothesis in (35a) than using stimuli produced by an English speaker would have been, because all else being equal we would expect that in an NC₁VNC₂ sequence there should be less nasalization in the intervening V when that NC₁VNC₂ sequence is produced by a Spanish speaker.

In order to facilitate analysis of the productions, a larger number of forms were recorded than were used in the task. For the recorded items, the first consonant (C_1) was /p/, /t/, or /k/; the second consonant or consonant sequence (C_2) was /m/, /mb/, /mp/, /n/, /nd/, /nt/, /ɲ/, or /ɲtʃ/; and the third consonant or consonant sequence (C_3) was d/, /n/, /nd/, or /nt/. In all cases, C_1 , C_2 and C_3 were followed by /a/. Crossing these properties led to 120 forms, like *pamanta*, *kantanta*, and *tandada*. The speaker was given a list with these 120 forms, plus a filler form at either end, and asked to read the list twice at a normal speech rate. Recordings were made with a Marantz PMD-661 MKIII solid-state recorder and a Shure SM-35 microphone in a soundproof booth at New York University.

Stimuli were created from these recordings. The contrast of interest in this experiment was N–ND, so C_2 in the “same” items contained either identical nasals or identical voiced nasal-stop clusters, and C_2 in the “different” items contained one of each (see (36)). This contrast was compared across four contexts: /d/, /n/, /nd/, and /nt/ in C_3 . C_1 was a filler consonant and was balanced across /p/, /t/, and /k/. For “same” items, two recordings of the same word were used where possible; for the 3 forms where there was only one fluent production (*pambanda*, *pandada*, *tandanda*), the fluent recording was duplicated). For “different” items, recordings chosen were those whose intonation matched most closely. This resulted in a set of 96 stimuli that were balanced across all conditions.

(36) Examples of “same” and “different” items

| Same | | Different | |
|------------|------------------------|------------|-----------------------|
| Comparison | Example | Comparison | Example |
| m–m | <i>tamada-tamada</i> | m–mb | <i>tamada-tambada</i> |
| mb–mb | <i>tambada-tambada</i> | mb–m | <i>tambada-tamada</i> |
| n–n | <i>tanada-tanada</i> | n–nd | <i>tanada-tandada</i> |
| nd–nd | <i>tandada-tandada</i> | nd–n | <i>tandada-tanada</i> |

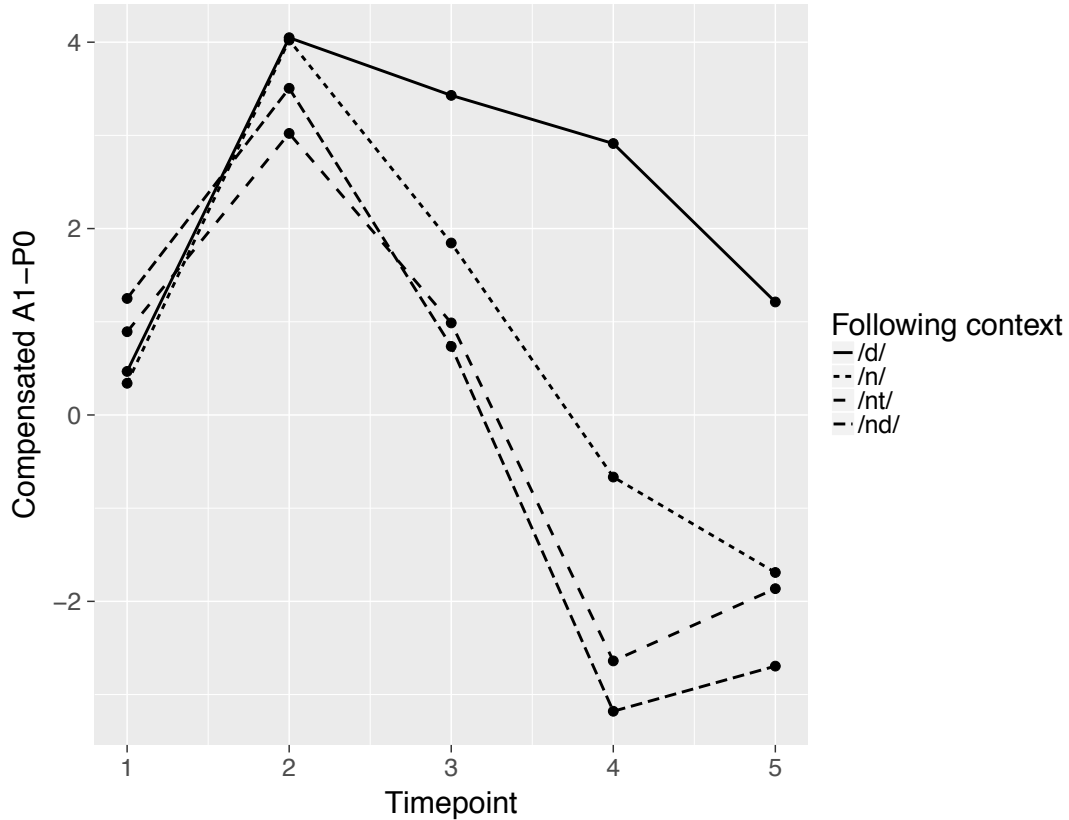
An AX task with these items allows us to test the hypotheses in (35) as follows. First, varying the identity of C_3 allow us to test the hypothesis that discrimination of N and NC should depend on the amount of nasalization in the intermediate vowel. If vowels are more nasalized before /nd/ than before /d/, for example, we would expect listeners to be more sensitive to the distinction between *pamada-pambada* than they are to the distinction between *pamanda-pambanda*. Second, varying the identity of C_2 allows us to test the hypothesis that discrimination of N–NC should depend on the duration of NC's release. If releases of [nd] are longer than those of [mb], for example, then we would expect listeners to be more sensitive to the distinction between *pananda-pandanda* than they are to the distinction between *pamanda-pambanda*. As specific predictions regarding listener behavior depend on acoustic properties of the speakers' productions, I investigate those next.

4.2 Acoustic properties of productions

To quantify the amount of nasalization in vowels preceding /d/, /n/, /nd/, and /nt/, I submitted each of the 240 words recorded to the Nasality Automeasure Script Package (Styler & Scarborough 2015). The decision to use all recordings (not just those incorporated into the stimuli) was made to heighten statistical power by increasing the number of tokens in each comparison group (see Styler & Scarborough 2015 on this recommendation for A1-P0 measurement). The compensated A1-P0 was measured at five equally spaced timepoints throughout the vowel between C_2 and C_3 (e.g. *pambada*); timepoints 1 and 5 were offset 5 ms. from the beginning and end of the vowel. Of 1200 possible measurements, the script took 1173. The y axis in Figure 4 is average compensated

A1-P0; lower A1-P0 measures are correlated with an increased amount of nasalization. The relative ordering of the following contexts in the key represents their relative ordering at Timepoint 5.

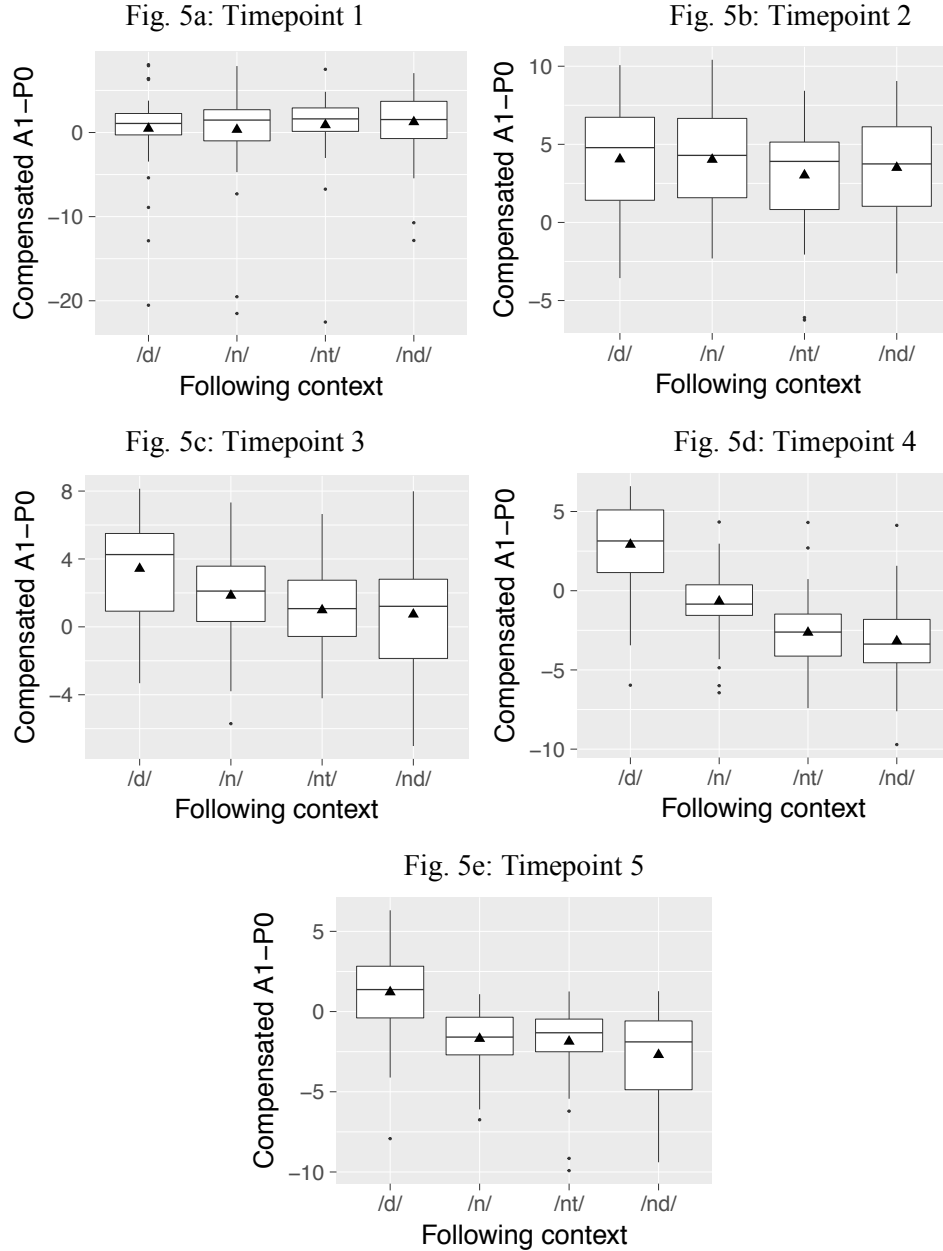
Figure 4: Compensated A1-P0 in Spanish vowels by following context



Several things are apparent. First, effects of anticipatory nasalization in this speaker's productions only extend to around the vowel's midpoint: the mean A1-P0 for vowels preceding /d/ is considerably higher at Timepoints 3-5 than are the mean values of vowels that precede an onset or a coda nasal, but this difference is mostly neutralized at earlier timepoints. Second, the amount of anticipatory nasalization depends on the onset vs. coda status of the nasal in C_3 : starting at timepoint 2-3, vowels preceding [nd], [nt] are more nasalized than vowels preceding [n]. Finally, the relationship between [nd] and [nt] changes over the vowel's timecourse. At Timepoints 1-2, the vowel preceding [nt] is more nasalized than the vowel preceding [nd]; at Timepoints 3-5, the reverse holds.

The boxplots in Figure 5 provide a better sense of the relationship between the categories at each timepoint by plotting by-timepoint A1-P0 values according to C_3 's identity.

Figure 5: compensated A1-P0 in Spanish vowels by timepoint



To determine which differences were meaningful, a linear regression was fit to each timepoint with R's `lm` function. The dependent variable was compensated A1-P0, and the independent variable was the identity of C_3 . This predictor was helmert-coded: comparisons were between the oral and nasal contexts (/d/ vs. /n/, /nt/, /nd/), the onset and coda nasal contexts (/n/ vs. /nt/, /nd/), and the voiceless and voiced NCs (/nt/ vs. /nd/). Generally speaking, the models found asymmetries in A1-P0 between the oral and nasal contexts as well as the prevocalic vs. non-prevocalic nasal contexts at the midpoint of the vowel and later. Full results are summarized in (37). A positive coefficient indicates that the first term in the comparison has a higher A1-P0 (or, is less nasal); a negative

coefficient indicates that the second term's is higher. Note that in (37), the significance level is taken to be $p < .01$, to correct for multiple comparisons (with five tests, the Bonferroni correction is $.05 / 5 = .01$).¹⁴

(37) Statistical analyses of nasalization data

| Following context | A1-P0 significantly different at timepoint? | | | | |
|-------------------------|---|--------------------------------------|---|--|---|
| | T1 | T2 | T3 | T4 | T5 |
| /d/ vs. /n/, /nt/, /nd/ | No ($t = -0.53$, $p = .60$) | No ($t = 1.09$, $p = .28$) | Yes ($t = 5.27$, $p < .001$) | Yes ($t = 14.73$, $p < .001$) | Yes ($t = 9.18$, $p < .001$) |
| /n/ vs. /nt/, /nd/ | No ($t = -1.00$, $p = .32$) | No ($t = 1.45$, $p = .15$) | Trending ($t = 2.17$, $p = .03$) | Yes ($t = 6.12$, $p < .001$) | No ($t = 1.54$, $p = .12$) |
| /nt/ vs. /nd/ | No ($t = -0.42$, $p = .68$) | No ($t = -0.80$, $p = .43$) | No ($t = 0.48$, $p = .63$) | No ($t = 1.26$, $p = .21$) | Trending ($t = 1.86$, $p = .06$) |

For the experiment, predictions regarding listener behavior depend on what is attended to while the listener attempts to determine if C_2 in a word like *tambanda* is an N or NC. If the listener makes the distinction using only properties of the consonantal release and the oral vs. nasal quality of the first part of the following vowel, we would not expect discrimination of N vs. NC to depend at all on the identity of C_3 . If however the listener's decision process takes into account the oral vs. nasal quality of the following vowel at its midpoint or later, we might expect to find that their response patterns mirror acoustic properties of the stimuli at timepoints 3-5. These predictions are in (38).

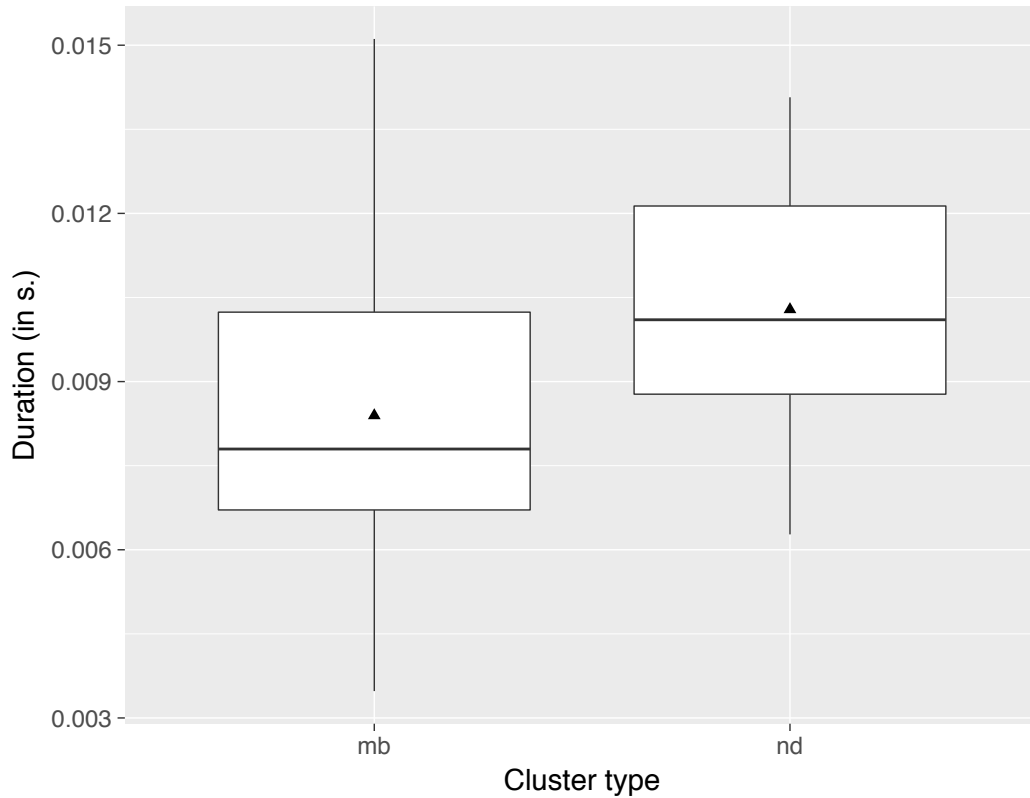
(38) Predictions given properties of vowel at timepoints 3-5

| C_3 | Sample item | /d/ vs. others | /n/ vs. /nd/, /nt/ | /nd/ vs. /nt/ |
|-------|-------------------------|----------------|--------------------|---------------|
| /d/ | <i>tamada-tambada</i> | More sensitive | | |
| /n/ | <i>tamana-tambana</i> | Less sensitive | More sensitive | |
| /nt/ | <i>tamanda-tambanda</i> | | Less sensitive | No difference |
| /nd/ | <i>tamanta-tambanta</i> | | | |

The second manipulation has to do with the identity of C_2 , which was either labial (/m/ or /mb/) or alveolar (/n/ or /nd/). To know if listeners should respond differently to these two stimulus types, it is necessary to know if release duration differs by place of articulation. To determine this, I measured the duration of the release, defined here as the combined duration of burst and VOT, of each /mb/ and /nd/ recorded (49 in total, with 25 /nd/ and 24 /mb/). Figure 6 shows that the release of /nd/ is longer than the release of /mb/ ($t = 2.63$, $p < .05$, linear regression).

¹⁴ A way to avoid multiple comparisons is to fit a model to the data that includes predictors for C_3 identity and Timepoint. Such a model finds a number of significant interactions between the two predictors. To interpret these interactions I subsetting the data by Timepoint and looked at the comparisons only within the C_3 identity predictor; the results of this further analysis are what is reported in (38).

Figure 6: release duration of [mb] and [nd]



The prediction in this case is straightforward: listeners may be more sensitive to the distinction between /n/ and /nd/ (where the oral release is longer) than they are to the distinction between /m/ and /mb/ (where the release is shorter). Note that the difference between these two categories is small: the mean release durations for [mb] and [nd] are 8 ms. and 10 ms., respectively. Probing this distinction was an intentionally conservative choice. If listeners are more sensitive to the /m/ vs. /mb/ distinction than they are to /n/ vs. /nd/, one can reasonably expect that listeners will also be sensitive to greater differences in release duration (like that between /mb/ vs. /ndʒ/ or /mp/).¹⁵

4.3 Procedure

39 participants, all native English speakers, were recruited from a combination of flyers, the NYU Facebook community, and Craigslist. Participants completed the experiment in a quiet room wearing Audio Technica ATH-ANC9 headphones and were compensated for their time.

¹⁵ It is also possible that listeners will respond to other differences between the labial and coronal series, for example aspects of their overall duration. The mean durations for the relevant N–NC pairs are: /m/ (106 ms.), /n/ (117 ms.), /mb/ (160 ms.) and /nd/ (156 ms.). A linear regression finds a significant interaction of consonant type and place, indicating that the N–NC durational difference is magnified in the labial series; $t = 2.00$, $p < .05$). If listeners' decisions about whether two recordings are "same" or "different" depend on this durational difference, we might expect them to be more sensitive to the distinction between /m/ and /mb/ than they are to the distinction between /n/ and /nd/, as a function of the labial series' greater durational difference. The fact that listeners did not behave this way (see Section 4.4) indicates that they pay attention to differences in the duration of the release, not to overall durational properties of the consonants.

During the experiment, participants were presented with 8 trial items: 4 “same” (*kananta*, *tanyana*, *tantada*, *panchana*) and 4 “different”, which did not contain comparisons repeated in the test items (*kanyanta-tampada*, *tanyanta-pampana*, *kananta-kantanta*, *padanta-panata*). The block of 96 test items followed. While a sound file played, a black dot appeared on the screen; participants were directed to decide during this period if they were hearing two different recordings of the same word or two recordings of different words. After the recording finished, a new screen appeared, with “Same (1)” at the left edge and “Different (0)” at the right. Participants were instructed to press 1 if they thought the two recordings were of the same word, and 0 if they thought the two recordings were of different words. They were asked to indicate their responses as soon as possible after the black dot disappeared (but not beforehand), and warned that if they did not respond quickly the experiment would move on to the next set of recordings. For all stimuli the ISI was 250 ms. and the maximum response time was 1500 ms.¹⁶

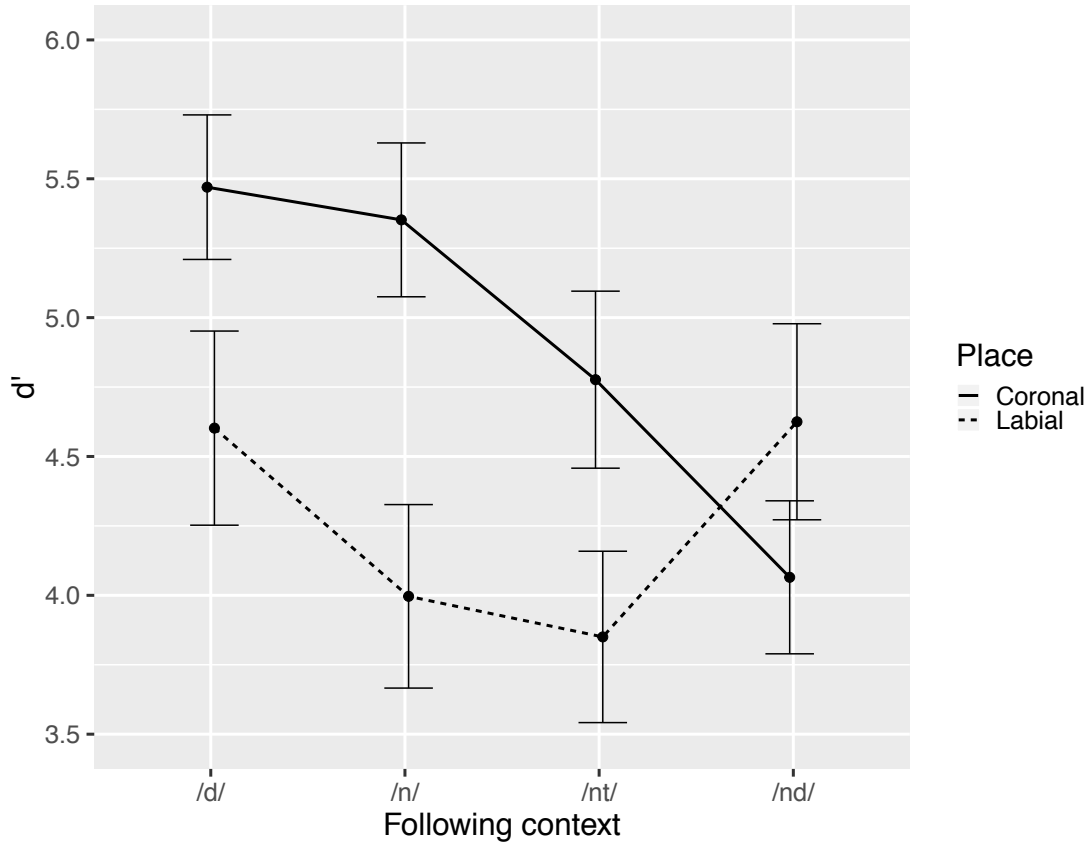
4.4 Results and discussion

Accuracy was above chance for both types of item; the hit rate (a correct “different” answer for a “different” item) was 81% and the false alarm rate (an incorrect “different” answer for a “same” item) was 12%. Results are plotted by C_3 context in Figure 9, with the two series representing the by-participant d' s for labial and coronal C_2 (dots indicate the mean value; error bars mark the standard error).¹⁷ These d' values were obtained from MacMillan & Creelman (2005:A5.4) and assume the differencing model, as is appropriate for an AX task with a roving design. The lower the d' , the less sensitive participants were to whether items in that group were “same” or “different”. The lines in Figure 7 are included as an aid to interpretation and do not represent change over time.

¹⁶ A reviewer worries about the short ISI, as participants could have used any available acoustic difference to discriminate between A and X, instead of using categories. There are several reasons to believe this is not a valid worry. First, if listeners chose “different” on the basis of any acoustic difference, the overall rate of “different” choices would be high, as almost all stimuli contained two different recordings. Yet 88.1% of the “same” items received a “same” response, suggesting that participants likely ignored non-contrastive differences between A and X. Second, the stimuli were long, meaning that more than 250 ms. elapsed before a decision could be made: on average, 956 ms. elapsed between the offset of A’s C_2 (e.g. *m* in *pamanta*) and the offset of X’s C_2 (e.g. *mb* in *pambanta*). Third, the crucial comparisons participants made were between-category comparisons of consonants. Work by Pisoni (1973) indicates that, for such comparisons, participants likely rely on phonemic categorization at all ISIs. Finally, even if participants were relying on auditory short-term memory, it is not clear how this would affect the interpretation of the results.

¹⁷ In addition to being a standard way of analyzing responses to an AX task, d' was useful for these data because response strategies appeared to vary substantially across conditions. For example, the false alarm rate for items where $C_3 = /d/$ (7.2%) was about half the false alarm rate for items where $C_3 = /nt/$ (14.1%).

Figure 7: averaged d' across participants by C₂ and C₃ identity



A mixed linear regression was fit to the d' values using the lmer function of R's lme4 package (Bates et al. 2015). The response variable was d'; dependent variables included the identity of C₃ (helmert-coded, with comparisons between /d/ vs. all others, /n/ vs. /nt/, /nd/, and /nt/ vs. /nd/), C₂'s place of articulation (sum-coded, with labial as the reference level), and an interaction between the two. By-participant random slopes for C₃'s identity and C₂'s place of articulation were also included. *p* values in (39) were calculated with R's lmerTest package (Kuznetsova et al. 2017).¹⁸

(39) Summary of full statistical model

| Factor | Coefficient | <i>t</i> value | Significant? |
|---|-------------|----------------|----------------------------|
| a. Intercept | 4.56 | — | — |
| b. C ₃ : /d/ vs. all others | 0.59 | 3.64 | Yes (<i>p</i> < .001) |
| c. C ₃ : /n/ vs. /nt/, /nd/ | 0.39 | 1.86 | Trending (<i>p</i> = .07) |
| d. C ₃ : /nt/ vs. /nd/ | 0.04 | 0.18 | No (<i>p</i> > .1) |
| e. C ₂ : Coronal | 0.34 | 4.25 | Yes (<i>p</i> < .001) |
| f. C ₃ : /d/ vs. all others * C ₂ : Coronal | 0.16 | 1.02 | No (<i>p</i> > .1) |
| g. C ₃ : /n/ vs. /nt/, /nd/ * C ₂ : Coronal | 0.56 | 3.42 | Yes (<i>p</i> < .001) |
| h. C ₃ : /nt/ vs. /nd/ * C ₂ : Coronal | 0.71 | -3.69 | Yes (<i>p</i> < .001) |

¹⁸ Including an interaction results in an improved fit relative to a model with no interaction ($\chi^2(3) = 25.11, p < .001$).

The main effect in (39b) confirms that N–ND is more distinct when C_3 is /d/ than when it is /n/, /nt/, or /nd/ (so Δ *pmada-pambada* > Δ *panada-pambana*, *panada-pambanda*, *pananta-pambanta*). The main effect in (39e) confirms that, across contexts, the N–ND distinction is more perceptible for coronals than for labials (so Δ *panada-pandada* > Δ *panada-pambada*). These results parallel the acoustic data: the release of [mb] is shorter than that of [nd], and vowels preceding /d/ are, from their midpoint on, the most oral.¹⁹ (This latter correlation also suggests that listeners’ discrimination of N–ND is at least partially dependent on information later in the vowel.)

The interactions in (39g–h) indicate that the further comparisons across C_3 contexts are dependent on C_2 ’s identity. To investigate these effects more directly, separate models were fit to the labial and coronal data, including only those d’ values where C_3 = /n/, /nt/, or /nd/. The dependent variable was the identity of C_3 (helmert-coded, with comparisons between /n/ vs. /nt/, /nd/ and /nt/ vs. /nd/), and a random intercept was included for participant. These models are summarized in (40–41); note that the significance level is taken to be $p < .025$, to correct for multiple comparisons (with two tests, the Bonferroni correction is $.05 / 2 = .025$).

(40) Summary of statistical model for coronals

| | Factor | Coefficient | <i>t</i> value | Significant? |
|----|----------------------------|-------------|----------------|--------------------|
| a. | Intercept | 2.98 | – | – |
| b. | C_3 : /n/ vs. /nt/, /nd/ | 0.96 | 4.07 | Yes ($p < .001$) |
| c. | C_3 : /nt/ vs. /nd/ | 0.65 | -2.38 | Yes ($p < .025$) |

(41) Summary of statistical model for labials

| | Factor | Coefficient | <i>t</i> value | Significant? |
|----|----------------------------|-------------|----------------|--------------------|
| a. | Intercept | 2.88 | – | – |
| b. | C_3 : /n/ vs. /nt/, /nd/ | -0.19 | -0.70 | No ($p > .1$) |
| c. | C_3 : /nt/ vs. /nd/ | -0.79 | 2.41 | Yes ($p < .025$) |

For the coronals, (40b) indicates that [n–nd] is more perceptible when C_3 is /n/ than when it is /nt/ or /nd/ (so Δ *panana-pandana* > Δ *pananda-pandanda*, *pananta-pandanta*). This comparison across contexts was not significant for the labials (41b), indicating that the trending main effect in (39) was driven by the coronals. The comparison between C_3 = /nt/ and C_3 = /nd/ was significant for both places of articulation, though in opposite directions. For the coronals, discrimination was better before /nt/ (so Δ *pananta-pandanta* > Δ *pananda-pandanda*, (40c)); for the labials, discrimination was better before /nd/ (so Δ *pananda-pambanda* > Δ *pananta-pambanta* (41c)).

4.5 Summary

The experiment discussed here tested two hypotheses, which arose from a consideration of both typological and language-specific restrictions on NCD. These hypotheses are summarized in (42).

(42) Hypothesized perceptual factors

- The more nasalized a vowel following NC is, the more confusable NC is with N.
- The shorter an NC’s release, the more confusable the NC is with N.

¹⁹ A reviewer raises a concern that the durational difference between [mb] and [nd], 2 ms., is below the just noticeable difference for duration. While this is indeed a very small average difference, it is not clear to me what else could underlie the [m–mb] vs. [n–nd] distinction observed here.

The results are largely consistent with (42a-b): participants discriminate N–NC more reliably when it is in an oral context than when it is in a nasal context, and when NC's release is longer.²⁰ Beyond these results, the results differed by place of articulation. The coronal response data are consistent with the further hypothesis that discrimination of N–NC before /n/ should be more reliable than before /nd/ and /nt/, but the labial response data are not. In addition, neither of the significant comparisons between $C_3 = /nd/$ and $C_3 = /nt/$ were predicted given the acoustic data. (Subsetting the nasalization data by C_2 's place of articulation reveals no obvious acoustic differences that could explain the observed differences in response.) Given that the most reliable distinction in the acoustic data was that between the oral and nasal contexts, however, the lack of consistently significant effects for the more fine-grained comparisons is perhaps not surprising.

Narrowly, these results are consistent with the crucial hypotheses of the perceptually-based account of NCD developed in Sections 2-3; more broadly, they add to the body of evidence that perception of consonantal contrasts can be affected by non-local information (e.g. Gallagher 2010).

5 Further links between $NC\tilde{V}$ and NCD

Anticipatory nasalization of the intermediate vowel in $NC_1VN(C)_2$ is only one of the ways that an NC can come to precede a nasal(ized) vowel. Many languages also license contrasts in vocalic nasality, and in these languages $NC\tilde{V}$ sequences (where \tilde{V} is a phonemically nasal vowel) are in principle possible. All else being equal, we would expect that languages that prioritize maximally distinct N–NC contrasts should disprefer $NC\tilde{V}$ and $NC_1VN(C)_2$.

There are however differences in the amount of nasalization exhibited by contrastive and non-contrastively nasalized vowels. In the cases I am aware of, contrastively nasalized vowels are more nasalized than coarticulatorily nasalized vowels in both the extent and intensity of acoustic nasality (e.g. Cohn 1990 on French). We might expect NC to be more distinct from N before $VN(C)$, a context of generally lesser nasality, than it is before \tilde{V} , a context of generally greater nasality. If this asymmetry holds cross-linguistically, the predictions in (43) follow.

- (43) Predictions regarding $NC\tilde{V}$ and $NCVN(C)$
- a. If a language allows $NC\tilde{V}$, it should also allow $NC_1VN(C)_2$.
 - b. If a language bans $NC_1VN(C)_2$, it should also ban $NC\tilde{V}$.

As is true for all of the generalizations discussed in this article, (43a-b) follow from the hypothesis of licensing by cue (Steriade 1997): if N–NC is licensed in a context where it is less distinct, it should be licensed in all contexts where it is equally or more distinct. I show next that they hold.

5.1 Prediction 1: $NC\tilde{V}$ implies NC_1VN_2

To test the prediction that $NC\tilde{V}$ in a given language should imply $NC_1VN(C)_2$, I searched for languages that allow NCs and a vocalic nasality contrast. Languages were identified from reference grammars at MIT's Hayden Library and online periodicals. An important criterion for inclusion

²⁰ A reviewer proposes an alternative interpretation of this result, namely that discrimination of the N–NC contrast is impacted entirely by the identity of C_3 (and not the amount of regressive nasalization it does or does not induce). This is possible, but until a concrete rationale for this alternative interpretation can be provided, I continue to hypothesize that the relevant factor here is the nasalization of the intervening vowel.

was that an N–NC contrast exist: languages like Apinayé and Siriono, though identified by Maddieson (1984) as allowing NCs and a vocalic nasality contrast, do not qualify. In these and other South American languages, Ns and NCs are allophones conditioned by the quality of the neighboring vowels (e.g. Herbert 1986, Stanton 2018). As the focus here is on the effects of vocalic nasality on N–NC, these languages are not directly relevant for the discussion that follows.

Altogether, 23 relevant languages were identified (see the appendix for a full list). Of these 23, 12 allow NC \tilde{V} sequences; the fact that 11 do not speaks to the more general claim that NC \tilde{V} sequences are dispreferred. As predicted, all languages that allow NC \tilde{V} allow NC₁VN(C)₂. These results are in Table 3; where applicable, gloss translations are mine. For each language, I provide minimal or near-minimal pairs to support the claim that a contrast in vocalic nasality is licensed following NCs, as well as forms supporting the claim that these languages also allow NC₁VN(C)₂. (Note that for Lua and Mbum, only NC₁VN₂ forms are provided because NCs are prohibited outside of initial position. See Stanton 2016a:1108-10 for discussion of the distribution of NCs in these languages.)

Table 3: Languages that allow NC \tilde{V} also allow NCVN(C)

| Language (Source) | NCV–NC \tilde{V} | NCVN(C) |
|----------------------------|--|--|
| Day (Nougayrol 1979) | ndéé 'people' (p. 61) ndé 'little' (p. 61) | mbòmbórò 'jawbone' (p. 35) ndèèm 'to suffice' (p. 61) |
| Kabba (Moser 2004) | mbī 'ear' (p. 36) mbī 'nausea' (p. 36) | ngàm 'lie' (p. 20) mbámbá 'soldier' (p. 20) |
| Lua (Boyeldieu 1985) | mbàrì 'to flatten' (p. 43) mbá: 'regularly' (p. 43) | ndōŋ 'it's too wide, narrow' (p. 49) ndwāàm 'Ndam of Ndam' (p. 52) |
| Mbay (Keegan 1996) | mbòj 'in a panic' (p. 293) mbòj 'pleasantly' (p. 294) | ngōn 'son, daughter' (p. 355) mbínding 'very heavy' (p. 290) |
| Mbum (Hagège 1970) | nzáu 'spark' (p. 41) nzá 'balafon' (p. 59) | mbàm 'rain' (p. 30) ndàm 'poison' (p. 32) |
| Ngambay (Vandame 1963) | ndà 'to be white' (p. 197) ndá 'to pick' (p. 15) | ndàng 'to be crazy' (p. 9) mbūnā 'interval' (p. 197) |
| Ngbaka (Thomas 1963) | zālānzè 'orange' (p. 46) nzē 'blood' (p. 30) | mbàngà 'river sand' (p. 28) mbānā 'wing' (p. 50) |
| Nizaa (Endresen 1991) | mbæ 'to judge' (p. 42) mbēē 'to limp' (p. 42) | mbèmbèm 'wind instrument' (p. 48) ndaŋni 'disobedience' (p. 48) |
| Tinrin (Osumi 1995) | ŋdī 'leaf, be humid' (p. 17) ŋdū 'hawk' (p. 15) | ŋdāŋdōrō 'to hurt the foot...' (p. 5) ŋdinawa 'coconut leaves' (p. 290) |
| Vouté (Guarisma 1978) | ngór 'thinness' (p. 45) ngóō 'grass <i>sp.</i> ' (p. 45) | ngúŋ 'stick' (p. 45) ngónbé 'paddle' (p. 24) |
| Xârâcùù (Lynch 2002) | ba:ru 'two' (p. 768) mb ^w ā 'distant and invisible' (p. 768) | ndomb ^w a 'thing' (p. 775) mbanī: 'how many?' (p. 775) |
| Yakoma (Boyeldieu 1975) | pendá 'back' (p. 126) ndē 'different(ly)' (p. 100) | ngúni 'the water falls...' (p. 22) ngāmbií 'youngest' (p. 39) |

5.2 Prediction 2: *NC₁VN(C)₂ implies *NC \tilde{V}

To test the prediction that *NC₁VN(C)₂ implies *NC \tilde{V} , I attempted to find information about the vocalic inventories of each language included in the survey of NCD. Of the languages surveyed,

I was able to find this information for 43. Of these 43, only Sango (Samarin 1967), Saramaccan (McWhorter & Good 2012), and Zande (Gore 1931) license a contrast in vocalic nasality (44–46).

(44) Vowel nasality contrast in Sango (Samarin 1967:38)

- | | | | | | |
|----|----|----------|-----|----|-------------|
| a. | fú | 'to sew' | vs. | fũ | 'to smell' |
| b. | kε | 'to be' | vs. | kẽ | 'to refuse' |

(45) Vowel nasality contrast in Saramaccan (McWhorter & Good 2012:19)

- | | | | | | |
|----|------|----------|-----|------|--------|
| a. | péti | 'puddle' | vs. | pěti | 'comb' |
| b. | hási | 'horse' | vs. | hási | 'ant' |

(46) Vowel nasality contrast in Zande (Gore 1931:2,19)

- | | | | | | |
|----|-----|---------------|-----|-----|--------|
| a. | we | 'fire' | vs. | wẽ | 'thus' |
| b. | bau | 'plentifully' | vs. | baũ | 'lion' |

In none of these languages does it appear that NC \tilde{V} sequences are robustly attested. In the case of Saramaccan, McWhorter & Good (2012:26) note their rarity explicitly: the only NC \tilde{V} sequence in Saramaccan occurs in the ideophone gíngi/gingí 'suck fast', and even in this case there is variation between NCV and NC \tilde{V} . In the cases of Sango and Zande, these restrictions are not discussed explicitly but are inferred through the lack of NC \tilde{V} -containing forms in the cited sources.

The predictions outlined in (43), then, are verified.

6 Discussion and conclusions

This article has argued that typological, acoustic, and perceptual evidence are consistent with an analysis in which NCD is driven by constraints on the distinctiveness of the contrast between NC₁ and a plain nasal, N. Sections 6.1 and 6.2 discuss two possible alternative analyses, and Section 6.3 discusses some implications and concludes.

6.1 Alternative 1: a diachronic analysis

The proposed analysis claims that considerations of perceptual distinctiveness are an integral part of speakers' phonological competence (Flemming 2002, *a.o.*). But we should also consider the viability of a diachronic alternative (à la Ohala 1981, Blevins 2004, Moreton 2008): is it possible that considerations of N–NC contrast distinctiveness correlate with NCD not because they are part of the grammar, but because NCD reflects the fact that insufficiently distinct N–NC contrasts are more likely to be misapprehended and neutralized over time?

The primary difficulty for this alternative is that the kinds of alternations instantiating NCD are diverse and not all of them can be viewed as the result of diachronic neutralization. Given an illicit NC₁VNC₂ sequence, languages in the survey generally display one of three possible responses: deletion of C₁ (47), N₁ (48), or N₂ (49) (see also Jones 2000).²¹

²¹ In several cases (most notably the Eastern Ngumpin languages) the attested alternation is either N₂ deletion or N₂ denasalization, depending on whether NC₂ is homorganic or heterorganic (McConvell 1988:138). In addition, there is a potential case of C₂ nasalization in the western dialects of Gurindji (McConvell 1988:150, e.g. /ɲumpin+ku/ → [ɲumpin-ɲu] n.g.) though it is not clear to what extent this can be dissociated from a more general tendency in these dialects for NC to be realized as NN. This exhausts the attested responses to *NC₁VNC₂ that I am aware of. It is not clear to me

- (47) Deletion of C₁: Ngaju Dayak (Blust 2012:372)
- | | | | | |
|----|-------------|---|-------------|----------------|
| a. | /maN+bando/ | → | [ma-mando] | 'turn against' |
| | /maN+bagi/ | → | [mam-bagi] | 'divide' |
| b. | /maN+gundu/ | → | [ma-ŋundul] | 'wrap up' |
| | /maN+gila/ | → | [maŋ-gila] | 'drive crazy' |
- (48) Deletion of N₂: Gurindji (McConvell 1988:138)
- | | | | | |
|----|---------------|---|---------------|--------------------|
| a. | /kaŋɟu+mpal/ | → | [kaŋɟu-pal] | 'across below' |
| | /kajira+mpal/ | → | [kajira-mpal] | 'across the north' |
| b. | /kanka+mpa/ | → | [kanka-pa] | 'upstream' |
| | /kani+mpa/ | → | [kani-mpa] | 'downstream' |
- (49) Deletion of N₁: Timugon Murut (Blust 2012:367)
- | | | | | |
|----|---------------|---|--------------|---------------|
| a. | /maN+tumbuk/ | → | [ma-tumbuk] | 'thump' |
| | /man+tutu/ | → | [man-tutu] | 'pound' |
| b. | /saN+gonggom/ | → | [sa-gonggom] | 'one fistful' |
| | /son+dopo/ | → | [son-dopo] | 'one fathom' |

The alternations in (47) instantiate N–NC₁ neutralization as a response to an insufficiently distinct N–NC contrast, but the alternations in (48–49) cannot be characterized in this way. N₂ deletion (48) is a type of enhancement: by removing the source of coarticulatory nasalization, N–NC₁ is rendered more distinct. N₁ deletion (49) could also be conceived of as a type of enhancement: the contrast between C₁ and nothing could also be enhanced by removing the lefthand N. Contrast enhancement is generally harder to account for in a framework in which the role of phonetic information in phonology is relegated to diachrony: in order to render an insufficiently distinct contrast more distinct, the speaker must be aware that it is insufficiently distinct in the first place (though cf. Blevins 2004:285-289). Thus the existence of enhancement phenomena here and elsewhere suggests that contrast is a primitive of the synchronic grammar.

A reviewer notes that it is perhaps possible to account for the apparent enhancement phenomena in (48–49) by appealing to perceptual hypocorrection. While this is of course a possibility, it is not obvious to me what form such an analysis would take, nor am I aware of any existing concrete proposal along these lines. The point is only that, given the current analytical options on the table, synchronic analyses that treat contrast as a primitive fare better in accounting for the relationship between neutralization and enhancement phenomena (see also Stanton 2018a on this point).

6.2 Alternative 2: a co-occurrence constraint

A second alternative, due to Alderete (1997), Blust (2012), and others, is that NCD arises due to the activity of a co-occurrence constraint (*NC...NC) that penalizes words containing sequences of NCs. One of the stronger pieces of evidence against this analysis comes from generalizations discussed in Section 5: languages that allow NC \tilde{V} allow NC₁VNC₂, and languages that ban NC₁VNC₂ ban NC \tilde{V} . These generalizations would not be expected in a theory where NCD is

why these repairs are attested while others, e.g. lengthening of V, devoicing of C₁ in NC₁VNC₂, or insertion of a consonant between NC₁ and V are unattested. Given the small size of the survey (relative to the number of languages that have NCs) and its focus on C₁ deletion, it is entirely possible that such languages have not been discovered yet.

motivated by a co-occurrence constraint. Such a theory would not predict a link between the NCVNC and NC \tilde{V} , as the constraint penalizing NCVNC (*NC...NC) would not penalize NC \tilde{V} . The absence of such systems suggests that there is no constraint penalizing NCVNC or NC \tilde{V} to the exclusion of the other. Put differently, the observed link between the NC \tilde{V} and the NCVN(C) typologies suggests that the desire to avoid indistinct N–NC₁ contrasts is not just one possible motivation for NCD, but that it is the only possible motivation.

Beyond this, some aspects of the results discussed here are difficult for a co-occurrence-based analysis. I discuss first typological generalizations with no obvious explanation under this analysis; second, I discuss links between the generalizations and the extant acoustic and perceptual data.

In Section 2, it was shown that two broad generalizations characterize the typology of NCD: repair of NC₁VNC₂ implies repair of NC₁VN₂V, and repair of one of NC₁VNC₂ or NC₁VN₂ implies repair of the other. The second of these generalizations could be captured by proposing that the relevant constraint is actually one on co-occurring coda nasals (*N]_σ...N]_σ), but the first is more difficult for a co-occurrence-based account. While the ban on NC₁VNC₂ and NC₁VN₂ can be straightforwardly captured by *N]_σ...N]_σ, this constraint does not penalize NC₁VN₂V. It would be difficult to explain under this alternative analysis why repair of NC₁VN₂V implies satisfaction of *N]_σ...N]_σ. Furthermore, even if a co-occurrence constraint existed that was capable of penalizing NC₁VNC₂, NC₁VN₂, and NC₁VN₂V, without further amendment this constraint would not make predictions about directionality: it would penalize NC₁VN₂ and N₁VNC₂ equally. This is not the empirical result we want. Within the surveyed languages, restrictions on NC₁VN₂V are common but restrictions on N₁VNC₂ are unattested. This directional asymmetry is, however, predicted by the current contrast-based account. In N₁VNC₂V, all else being equal, NC₂ will be followed by an oral vowel, rendering it maximally distinct along the ORAL dimension. Put differently, the problem for NC₁VN₂V – that anticipatory nasalization from N₂ compromises cues to N–NC₁ – does not exist for N₁VNC₂V. Turning to the generalizations discussed in Section 3, it is not obvious under a co-occurrence-based account why the identity of NC₁, independent of the identity of NC₂, should affect the likelihood of NCD. In Ngaju Dayak, for example, a co-occurrence-based theory has no reason to expect that NCD should be more frequent when NC₁ is [mb] than it is when NC₁ is [ndʒ].²²

Finally, the links established in this article between NCD, acoustics, and perception would not be explicable under a co-occurrence-based theory of NCD. First, consider the relationship between the Yindjibarndi data discussed in Section 2 and one aspect of the perceptual data in Section 4. With respect to Yindjibarndi, it was shown that the context in which NCD occurs (when NC₂ is a labial or velar cluster) is the context in which the intermediate vowel carries the most coarticulatory nasalization. This finding is consistent with the perceptual data, where listeners generally became less sensitive to the contrast between N and a voiced NC as the amount of coarticulatory nasalization in the following vowel increased. Second, consider the relationship between the Ngaju Dayak data discussed in Section 3 and the other aspect of the perceptual data in Section 4. With respect to Ngaju Dayak, it was shown that increased rates of NCD are correlated with shorter stop releases. This finding is also consistent with the perceptual data, where listeners were less sensitive

²² A reviewer asks if languages exhibiting long-distance NCD have constraints on what can intervene. Such effects are potentially unexpected under a co-occurrence-based account, but expected under the present account, to the extent that intervening segments that block NCD also block nasalization and segments that are transparent to NCD perpetuate nasalization. Space prevents me from answering this question here, but see Stanton (2018b) on blocking in existing long-distance NCD cases and why these patterns are difficult to account for under a co-occurrence-based analysis.

to the distinction between N and voiced NC when the release of NC was shorter. This article has thus established that there are links between NCD, acoustics, and perception; these links are directly captured by the contrast-based analysis proposed throughout. A co-occurrence-based analysis of these same facts would be forced to treat the links established in this article as coincidences.

6.3 Implications for a theory of dissimilation

The overall conclusion is that NCD is motivated by constraints on contrast, not by co-occurrence constraints. This conclusion leads to a new understanding of the entities targeted by co-occurrence constraints and connects to prior work that investigates perceptual bases for co-occurrence restrictions (e.g. Ohala 1981, Hall 2007, Gallagher 2010). These points are discussed in turn.

NCD does not fit comfortably within the larger typology of dissimilation. Dissimilatory processes tend to target segments that share one or more features (e.g. [+labial] or [+spread glottis]). Nasal-stop sequences can be (but are not necessarily) treated as single segments by the language's phonology; regardless of its language-specific behavior, however, an NC can only be characterized using a sequence of features (see esp. Anderson 1976 on the difficulties of using a single feature matrix). And in Bennett's (2015) comprehensive survey of long-distance dissimilatory processes, the only processes that target sequences of features involve NCs ((50); see Bennett for references).

(50) Summary of Bennett's (2015) survey

| Description | Involved features | No. | Example language |
|--------------------|-------------------------|-----|------------------|
| C Place | [+lab], [+cor], [+dors] | 42 | Akkadian |
| Nasal | [+nasal] | 2 | Takelma |
| Laryngeal features | [+const. glottis], etc. | 29 | Aymara |
| Continuancy | [+continuant] | 5 | Chaha |
| Liquids/Rhotics | [±lateral] | 22 | Latin |
| Sibilants | [+strident] | 4 | Nkore-Kiga |
| Voicing | [-voice] | 29 | Kinyarwanda |
| NC sequences | [+nasal][−nasal] | 21 | Gurindji |

If we adopt the proposal that NCD can only be motivated by a constraint on contrast, it is possible to characterize the remaining restrictions in (50) by stating that co-occurrence constraints can target only a single feature or a feature bundle whose members are realized simultaneously. Possible co-occurrence constraints take the form $*[\alpha, \beta] \dots [\alpha, \beta]$ (where $[\alpha]$ and $[\beta]$ are realized simultaneously); I assume that co-occurrence constraints of the form $*[\alpha][\beta] \dots [\alpha][\beta]$ (where $[\alpha]$ and $[\beta]$ are realized sequentially) are not part of CON. Thus in addition to its ability to account for generalizations present in the typology of NCD, the contrast-based analysis proposed in this article allows us to formulate a more restrictive theory of co-occurrence constraints.

This discussion leads to a larger question regarding the nature of the remaining co-occurrence restrictions in (50): are dissimilatory effects really due to the activity of some constraint with the form $*[\alpha] \dots [\alpha]$, or can they ultimately be attributed to other factors? The proposal that constraints on contrast drive NCD has precedent in work arguing that certain other types of dissimilation are perceptually motivated. Hall (2007), for example, argues that /r/-dissimilation in English is due to perceptual hypercorrection: /r/ is most likely to disappear in contexts where its presence is masked by another /r/ (e.g. in coda position; $p[\partial]ticular$ vs. $p[\partial]ticular$). Gallagher (2010) argues on the

basis of typological and experimental evidence that laryngeal co-occurrence restrictions are due to a constraint on contrast distinctiveness: words with multiple laryngeally marked segments (e.g. [k'ap'i]) are confusable with words that have only one (e.g. [k'api]).

Whether or not all of the dissimilatory processes in (50) can be attributed to phonetically-grounded constraints, as hypothesized by Ohala (1981), remains to be seen (though see Hall et al. 2017 for some critical discussion). But the current proposal that NCD is driven by constraints on contrast advances the discussion in two ways. First, the results discussed here strengthen the claim that at least some types of dissimilation are motivated not by co-occurrence constraints but by constraints that disprefer the perceptual consequences of co-occurrence. Second, it suggests that the targets of co-occurrence constraints must be restricted to single or simultaneously-implemented features.

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