# Predicting distributional restrictions on prenasalized stops*

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**Abstract**

Previous studies on prenasalized stops (NCs) focus mainly on issues of derivation and classification, but little is known about their distributional properties. The current study fills this gap. I present results of a survey documenting positional restrictions on NCs, and show that there are predictable and systematic constraints on their distribution. The major finding is that NCs are optimally licensed in contexts where they are perceptually distinct from plain oral and nasal stops. I provide an analysis referencing auditory factors, and show that a perceptual account explains all attested patterns.

## 1 Introduction

Prenasalized stops (NCs) are a type of phonetically complex segment composed of two sequenced parts: a nasal portion acoustically similar to a pure nasal consonant (N) followed by an oral portion acoustically similar to a pure oral consonant (C) (Burton et al. 1992). NCs are typically found in the languages of Africa, Oceania, and South America (Herbert 1986). A sample stop inventory containing NCs – that of Lua (Atlantic-Congo; Boyeldieu 1985) – is below (1).

(1) Stop inventory of Lua (Boyeldieu 1985)

| | *Bilabial* | *Alveolar* | *Palatal* | *Velar* |
|---|---|---|---|---|
| *Voiceless* | p | t | c | k |
| *Voiced* | b | d | ɟ | g |
| *Prenasalized* | mb | nd | ɲɟ | ŋg |
| *Implosive* | ɓ | ɗ | | ʔ |
| *Nasal* | m | n | ɲ | |

How do NC segments differ from NC clusters? The usual criteria are phonological (though cf. Riehl 2008, Cohn & Riehl 2012): nasal + stop sequences are treated as segments if they are licit in environments where other clusters (or sonority-violating clusters) are not. For example, in Lua (1), [mb], [nd], and [ŋg] can all appear word-initially, but initial clusters are otherwise disallowed (so ✓[mba], and ✓[nda], but *[tra], *[kla]). Here, there is a choice between positing a more complex inventory and proposing a more complex account of cluster phonotactics: do we say that the inventory contains complex segments, or do we propose an account for why the only licit initial clusters are NC sequences? The usual choice is to complicate the inventory.

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Most of the phonological literature focusing on NCs (e.g. Ferguson 1963, Poser 1979, Herbert 1986, Riehl 2008) has focused on issues of derivation and classification. How do we tell the difference between NC segments and NC clusters, and is this difference present at all levels of representation? Despite the wealth of studies focused on questions of this type, little attention has been paid to the surface distributional properties of NCs. In languages where NCs function phonologically as single segments, where are they licit and where are they banned? Are there any systematic, cross-linguistic constraints on their distribution and, if so, what is the nature of these constraints? The goal of the present study is to answer these two questions.

In what follows, I present evidence from a cross-linguistic survey demonstrating that there are consistent cross-linguistic implicational generalizations governing the distribution of NCs, and that these generalizations are predictable given consideration of the contexts in which NCs are distinct form, or, alternatively, confusable with their component parts (Ns and Cs). The major claim of this study is that *constraints on the distribution of NCs are constraints on contrast*: the presence of an N*NC or C*NC contrast in contexts where perceptual cues to the contrast are reduced entails presence of the contrast in contexts where cues are maximally available. I provide an analysis of the typology framed in Dispersion Theory (Flemming 2002), and show that all patterns receive a unified explanation grounded in auditory and articulatory factors.

The paper proceeds as follows. In §2, I summarize what is known about the acoustic and perceptual properties of NCs. Adopting the hypothesis of licensing by cue (Steriade 1997), I outline predictions regarding the expected cross-linguistic distribution of the N*NC and C*NC contrasts. In §3-§4, I present results of the survey and show that the empirical findings correlate precisely with the predictions. §5 extends and then verifies the predictions of the analysis for NC clusters, and §6 concludes. The appendices contain lists of languages consulted (A), summaries of cues and constraints (B), and results of factorial typologies (C).

# 2 Background and predictions

Here I summarize results of phonetic studies focusing on NCs (§2.1, §2.2), set forth predictions regarding the distribution of NCs (§2.3), and describe the survey undertaken to test them (§2.4).

## 2.1 Acoustics of NCs

Prenasalized stops are generally described as being composed of two component parts: a nasal stop, followed directly by an oral stop. A spectral study by Burton et al. (1992) suggests that this characterization is accurate. They demonstrate that, in Moru (a Central Sudanic language), the acoustic properties of NDs are more or less equivalent to the acoustic properties of their component parts, Ns and Ds. The onset nasal murmur of voiced NCs (NDs) is spectrally and durationally similar to the nasal murmur of Ns; the oral release bursts of NDs do not differ systematically in amplitude compared to the release bursts of plain Ds.

Burton et al. also show that NDs differ from both Ns and Ds due to a sharp decrease in amplitude, 16 dB on average, shortly before the release of the oral constriction (25-30 ms). This decrease in amplitude is indicative of velic closure and a subsequent buildup of air pressure. Segment-internally, NDs are like Ns in that both have an acoustically similar onset nasal murmur, but they differ from Ns due to the presence of a release burst, preceded by a brief period of oral occlusion. NDs are like Ds in that the two classes of segments have acoustically similar release bursts, but they differ from Ds primarily due to the presence of a nasal onset. Although the results reported by Burton et al. come from phonetic study of only one language, subsequent studies on the acoustics of NCs (Maddieson & Ladefoged 1993, Ladefoged & Maddieson 1996: 4.3, Riehl 2008, Cohn & Riehl 2012), have corroborated the general conclusion that NCs are made up of two acoustically distinct parts, essentially equivalent to an N followed by a C.

Voiceless prenasalized stops (NTs)[1] can be further distinguished from Ns and NDs by facts about their internal timing. Maddieson & Ladefoged (1993) show that, in Sukuma (Bantu), the duration of NT's nasal component is significantly shorter than the duration of a plain N. In addition, NTs have longer durations of oral closure and longer releases than do NDs (Maddieson & Ladefoged 1993 for Sukuma, Coetzee & Pretorius 2010 for Tswana). Cross-linguistically, it appears to be true that N takes up the majority of time allotted to ND, but N and T are more or less equally divided in NT (Maddieson & Ladefoged 1993, Ladefoged & Maddieson 1996: 4.3; see also Riehl 2008, Cohn & Riehl 2012). Schematic illustrations are in (2). Additionally, the difference in burst amplitude between Ns and NTs is presumably greater than is the difference between Ns and NDs.

(2) Internal timing of NCs

a. Internal timing of ND: N $>$ D

| | |
|---|---|
| N | D |

b. Internal timing of NT: N $\approx$ T

| | |
|---|---|
| N | T |

NCs can also differ from other consonants according to the length of a preceding vowel. In Sukuma (Maddieson & Ladefoged 1993), vowels preceding NTs are significantly shorter than those preceding Ns or NDs. In some languages, vowels preceding NDs are longer than vowels preceding Ns; this effect, however, is language-dependent. Languages where N*ND differ as a function of V1 duration are Luganda and Sukuma (Maddieson & Ladefoged 1993) CiYao and Runyambo (Hubbard 1995); languages where N and ND are not differentiated in this way include Fijian (Maddieson 1989), CiTonga (Hubbard 1995), Tamambo and Erromangan (Riehl 2008: 113-116).

NCs, Cs, and Ns can also be differentiated by the quality of surrounding vowels. In languages where oral and nasal vowels do not contrast, NCs are always followed by oral vowels, and Ns are always followed by nasal vowels. Evidence from a variety of languages suggests that carryover nasalization is universal: I have not found reports of languages with NCs that lack perseveratory nasal coarticulation. Instrumental evidence for post-N nasalization comes from Ikalanga (Beddor & Onsuwan 2003), Sebikotane Saafi (Stanton 2012), Tamambo and Erromangan (Riehl 2008); impressionistic evidence comes from Sundanese (Robins 1957), Rejang (Coady & McGinn 1982), Acehnese (Durie 1985: 25), Ulu Muar Malay, and three Dayak languages (Court 1970)[2]. Schematic illustrations follow in (3).

[1] Riehl (2008: 52ff) claims that voiceless prenasalized stops do not exist, but I believe that this conclusion is premature. One of Riehl's main diagnostics for unary status is that the sequence be inseparable – in other words, in a languages that lacks voiced obstruents, the NC sequence /mb/ must be treated as a segment. In a language that has voiced obstruents, /mb/ could be either a segment or a cluster, depending on other facts about the language's phonology. By this logic, languages that lack voiceless obstruents but have NT sequences must have voiceless prenasalized stops. An example of such a language is Makaa (Heath 2003), which lacks plain /p/ but has /mp/. Because /mp/ in Makaa is inseparable, it should be treated as a segment in Riehl's framework. Many other examples of inseparable NT clusters exist; for additional examples, see Meinhof (1932: 158) on Kongo, and Halpert (2012) on Zulu.

[2] Of course, impressionistic evidence is less significant than instrumental evidence, but I cite both to be exhaustive.

(3) Vowel quality following N and NC (V1 quality)

a. Vowels following NC: always oral (V)

| NC | V |
|---|---|

b. Vowels following N: always nasal (Ṽ)

| N | Ṽ |
|---|---|

A similar difference in vowel quality is apparent, in some languages, for vowels preceding Cs vs. NCs. Vowels preceding Cs are oral and, in many cases, vowels preceding NCs are nasalized. Instrumental evidence for pre-NC nasalization comes from Sukuma (Maddieson & Ladefoged 1993) and Tamambo (Riehl 2008: 151-156); impressionistic descriptions of other languages report the same pattern (Vandame 1963: 17 for Ngambay, Donohue 1999: 29 for Tukang Besi, Herbert 1976: 347, 350-1 and references there for others). There are, however, languages where pre-NC vowels do not appear to be nasalized: Maddieson & Ladefoged (1993) show that Luganda speakers do not nasalize pre-NC vowels (though cf. Herbert 1986). See (4) for summary illustrations.

(4) Vowel quality preceding C and NC (V2 quality)

a. Vowels preceding NC: often nasal (Ṽ)

| Ṽ | NC |
|---|---|

b. Vowels preceding C: always oral (V)

| V | C |
|---|---|

A table summarizing the discussion above of the known acoustic differences between NCs and other segment types is below (5). Note that these are only *potential* differences: all are attested in the global typology, but not all will necessarily be present in a given language or context.

(5) Summary of potential acoustic distinctions[3]

| | *N*ND* | *N*NT* | *D*ND* | *T*NT* | *ND*NT* |
|---|---|---|---|---|---|
| *V1 duration* | Δ V1 dur. | Δ V1 dur. | Δ V1 dur. | | Δ V1 dur. |
| *N duration* | | Δ N dur. | Δ N dur. | Δ N dur. | Δ N dur. |
| *V1 quality* | | | Δ nasal | Δ nasal | |
| *V2 quality* | Δ nasal | Δ nasal | | | |
| *Internal cues* | Δ burst | Δ burst | Δ nasal form. | Δ nasal form. | Δ burst |

## 2.2 Perception of the N*NC and C*NC contrasts

Given the multiplicity of cues just outlined, we might expect both internal and transitional cues to play a role in perception of the N*NC and C*NC contrasts. This section summarizes results of a two-part perceptual experiment (Beddor & Onsuwan 2003) probing the relative importance of internal and external cues to the N*NC and C*NC contrasts in Ikalanga (Bantu), and supplements the discussion with results from Kaplan's (2008) perceptual study on N*NC contrasts in English.

A potential concern worth highlighting now is that we know very little about cross-linguistic acoustics and perception of the N*NC and C*NC contrasts, and that the results described here may

[3] Abbreviations used in the table: "Δ" = a perceptible difference in; dur. = duration; form. = formants. Citations and justifications for all noted differences are in the above text.

not be representative. While it may very well be the case that the relevant cues to the N*NC and C*NC contrasts are different or weighted differently across languages, this has yet to be shown. For the time being I take the existing results to be representative, as they are all we know.

### 2.2.1 Perception of N*NC

In the first task described by Beddor & Onsuwan (2003), Ikalanga listeners were asked to judge whether a given stimulus contained an N or an ND. The relative duration of the oral occlusion was co-varied with the relative duration of acoustic nasality present in a following vowel. Stimuli were identified as Ns when lacking a release burst and increasingly as NDs given the presence of an oral release burst and an oral occlusion of increasing duration. Simplifying slightly, these results suggest that an important internal cue to the contrast between Ns and ND is the presence of ND's oral closure and release burst. I refer to these together as one cue, ∆ burst, in (6).

(6) Internal cue to the N*ND contrast
∆ burst (where ∆ = a perceptible difference in)

In addition, vowel quality following Ns and NDs had a large effect on consonant identification. Ns were most identifiable when followed by nasal vowels (Ṽs), and most confusable with NDs when followed by oral vowels (Vs). The opposite holds for NDs: NDs were most identifiable when followed by Vs, and most confusable with Ns when followed by Ṽs. These results indicate that an important external cue to the N*NC contrast in Ikalanga is a difference in nasal vs. oral CV transitions[4]. Ns and NDs are most distinct when Ns are followed by nasal CV transitions and NDs are followed by oral CV transitions (7).

(7) External cue to the N*ND contrast
∆ (nasal vs. oral) CV transitions

Speaker responses indicate that the internal and external cues to the N*ND contrast are not equally important. Reliable identification of the contrast between Ns and NDs is dependent on the presence of external cues: Ns must be followed by nasalized vowels for accurate identification. On the basis of this asymmetry, Beddor & Onsuwan (2003: 3) conclude that external cues are both "necessary and sufficient" for perception of the N*NC contrast. Impressionistic evidence suggests that the quality of a following vowel is a vital cue to the N*ND contrast in many other languages, including Sundanese (Robins 1957), Rejang (Coady & McGinn 1982), Acehnese (Durie 1985: 25), Tamambo and Erromangan (Riehl 2008: 173-177), and several Dayak languages (Court 1970).

If external cues are essential for accurate perception of N*ND, then N*ND should be distinct before a vowel, where CV transitions are present, but confusable word-finally, where CV transitions are absent. Results from a perceptual study on the distinctions among Ns and released NC clusters in English (Kaplan 2008) confirm this prediction[5]. While Ns and NDs were reliably identified intervocalically, all subjects frequently misidentified final NDs as Ns, and a subset of those subjects also frequently misidentified final Ns as NDs. Thus the N*ND contrast is distinct where external cues are present (prevocalically) but confusable where external cues are absent (word-finally).

[4]Here the term 'transitions' means more broadly 'transitional nasalization', the period of nasality in vowels following Ns (and the absence of this nasality in vowels following Cs or NCs).

[5]Kaplan's is a study on clusters, but I do not expect that the results would differ according to sequence type. See §5.

Kaplan's results also suggest that word-final N*NT is more distinct than is word-final N*ND. The presence of a following vowel appears to be less important to the N*NT contrast than it is to the N*ND contrast, presumably because the N*NT contrast is marked by a number of non-release-associated cues (outlined in §2.1) that N*ND is not. Note however that speakers were less accurate at identifying final NTs than they are at identifying intervocalic NTs (Kaplan 2008: 24), suggesting that Δ CV transitions, although less necessary, is still an important cue to the N*NT contrast.

#### 2.2.2 Perception of D*ND

Beddor & Onsuwan (2003)'s second identification task reveals that both internal and external cues are important to the Ikalanga D*ND contrast. Stimuli were created by co-varying the temporal extent of acoustic nasality in the preceding vowel with the duration of ND's nasal formants. Speakers reliably identified the stimuli as Ds when the consonant was entirely oral, and increasingly as NDs as the duration of consonantal nasality increased. An important internal cue to the D*ND contrast is a difference in the presence of consonantal nasal formants: NDs have them, but Ds do not (8).

(8) Internal cues to D*ND contrast
Δ nasal consonant formants

Identification of Ds and NDs is also affected by the quality of the preceding vowel. Though the magnitude of this effect was fairly small, stimuli were more likely to be identified as Ds when preceded by Vs, and more likely to be identified as NDs when preceded by Ṽs. Thus an external cue to the D*ND contrast is the presence of a difference in oral vs. nasal VC transitions: Ds and NDs are most distinct when Ds are preceded by Vs, and NDs are preceded by Ṽs (9).

(9) External cues to D*ND contrast
Δ (oral vs. nasal) VC transitions

Recall that reliable identification of Ns and NDs in Ikalanga is affected by the presence of internal cues (Δ burst), but dependent on the presence of external cues (Δ CV transitions). For the D*ND contrast, however, the presence of internal cues alone is sufficient for reliable identification. Beddor & Onsuwan note that their findings parallel the acoustics of NDs in Ikalanga: while the nasal portion of ND is long, the oral portion is often 10% or less of the entire segmental duration (as is true for many other languages; see §2.1). Ds and NDs can be reliably identified when appropriate VC transitions are absent because the nasal portion of ND is long, and is sufficient to cue the contrast. By contrast, the oral portion of ND is short, so the internal cues to N*ND are less robust.

### 2.3 Predictions

Here I adopt the hypothesis of licensing by cue (Steriade 1997): if two contexts ($C_1$ and $C_2$) differ in that some contrast x*y is better cued in $C_1$ than it is in $C_2$, then the presence of x*y in $C_2$ implies its presence in $C_1$. Adopting this hypothesis allows us to build off the known cues to the N*NC and C*NC contrasts and outline several predictions regarding their distribution. Two predictions based on the cues discussed in §2.2 are in (10) and (11)[6].

[6] An additional prediction regarding the distribution of vowel qualities following NCs is that NCṼ should asymmetrically imply NCV, as NCs are more distinct from Ns before Vs than Ṽs. I verified this prediction through a small survey of 15 languages allowing both NCs and phonemic nasal vowels. I leave a full discussion of this survey, and the interactions

(10) *Prediction 1: distribution of N*NC*
A final N*NC contrast asymmetrically implies a prevocalic N*NC contrast.

(11) *Prediction 2: distribution of C*NC*
An initial C*NC contrast asymmetrically implies a postvocalic C*NC contrast.

We expect final N*NC to imply prevocalic N*NC ((10)) because N*NC is better-cued in prevocalic position, where CV transitions are present. No language should license an N*NC contrast where CV transitions are absent (finally) but neutralize it where CV transitions are present (prevocalically). We expect initial C*NC to imply postvocalic C*NC ((11)) because C*NC is better-cued in postvocalic position, where VC transitions are present. No language should license C*NC where VC transitions are absent (initially) but neutralize it where VC transitions are present (post-V)[7]. In addition, as the results from Beddor & Onsuwan's study suggest that C*NC is less dependent on external cues than N*NC, we might expect more languages to license initial C*NC than final N*NC.

To understand how the predictions of the contrast-based account differ from alternatives, I consider now the predictions of an analysis where the licensing of certain feature values is dependent on their prosodic position (e.g. Goldsmith 1990, Rubach 1990, Lombardi 1995). The prediction in (10) can be captured under such an analysis: like other marked segment types, we might expect NCs to be preferred in onset position but disallowed in coda. The prediction in (11), however, cannot easily be captured by reference to prosodic position: it predicts that some kinds of NC onsets (in intervocalic position) should be preferred to others (in initial position). Furthermore, given that many languages *prefer* to license certain contrasts in initial position (Beckman 1998, Smith 2002, Barnes 2002), we might expect the prediction in (11) to be reversed. The point, in short, is that a prosodic analysis has no *a priori* reason to predict that postvocalic NCs should be preferred over word-initial NCs. A contrast-based analysis, however, does. The fact that (11) is the correct prediction (see §4) favors a contrast-based analysis of the distribution of NCs as the analysis predicts all and only the observed contextual asymmetries in the distribution of NCs.

## 2.4 Testing the predictions

To test the predictions in (10) and (11), I conducted a survey documenting positional restrictions on the N*NC and C*NC contrasts. Languages with NCs were identified through a large-scale investigation spanning many journal articles, databases (e.g. SAPhon, Michael et al. 2012), and a large collection of reference grammars from three libraries. I used purely phonotactic criteria to distinguish between NC segments and clusters: if an NC sequence can appear where other clusters (or sonority-violating clusters) cannot, I treated it as a single segment[8]. An additional prerequisite for inclusion in the survey was that the language allow plain obstruent stops in initial, intervocalic, and word-final position. As NCs are best considered a kind of obstruent stop (see Maddieson 1984: 67-68, Steriade 1993), they ought to have the distributional properties of other stops.

The 50 languages included in the survey represent the totality of identified languages satisfying the criteria for inclusion. The only languages excluded were ones where the status of final obstruent stops was unclear. In Kalkatungu (Blake 1979), for example, unreleased [t] and the trill [r] are in

between consonantal and vocalic nasality, to future work.

[7] I did not consider other contexts here (i.e. pre- or post-consonantally) because there are very few languages in the survey that allow stops in these contexts.

[8] See §5 for evidence that the predictions in §2.3 hold regardless of NC sequence type.

free variation. It is unclear if the word-final [t] is a true example of a word-final obstruent stop, or just an unreleased allophone of /r/. The sample is representative of a variety of major language families: Afro-Asiatic (5), Arnhem (2), Austronesian (18), Indo-European (1), Niger-Congo (15), Nilo-Saharan (2), Pama-Nyungan (2), Trans-New Guinea (2), and three isolates. While the sample is largely composed of Austronesian and Niger-Congo languages, this is representative of the global distribution of languages with NCs. The results of the survey are discussed in §3 and §4.

## 3 Final NCs and the N*NC contrast

Results from the survey verify the prediction in (10): final N*NC asymmetrically implies prevocalic N*NC. §3.1 presents the survey results, and §3.2 provides a Dispersion Theoretic analysis of the typology. §3.3 discusses an alternative analysis, appealing to possible language-specific differences in the phonetics of NCs. §3.4 and §3.5 discuss the importance of Δ burst, and provide evidence that the link between perception and phonological contrast is synchronically active.

### 3.1 Survey results

Of the 50 surveyed languages, all license N*NC prevocalically, and 19 license N*NC prevocalically and finally. No language licenses N*NC finally only. Languages licensing N*NC both prevocalically (✓_V) and word-finally (✓V_#) are 'permissive'; languages licensing N*NC prevocalically only (✓_V, *V_#) are 'restrictive.' Examples of each type are below (12); see Appendix A for more.

(12) Results for N*NC contrast

| Permissive (✓_V, ✓V_#) | Restrictive (✓_V, *V_#) | Other (*_V, ✓V_#) |
|---|---|---|
| *19 languages, e.g.*<br>Avava (Crowley 2006a)<br>Naman (Crowley 2006b)<br>Páez (Rojas Curieux 1998) | *31 languages, e.g.*<br>Acehnese (Durie 1985)<br>Alawa (Sharpe 1972)<br>Lua (Boyeldieu 1985) | *0 languages* |

It is important to note that restrictions on the distribution of the final N*NC contrast cannot be attributed to more general phonotactic constraints. For example, the distribution of NCs does not necessarily parallel the distribution of clusters. Alawa (Sharpe 1972) permits final clusters but bans final NCs; many languages, including Boukhou Saafi (Mbodj 1983) and Naman (Crowley 2006b), permit final NCs but ban final clusters. The presence or absence of final NCs also does not correlate precisely with the status of final released stops. Languages like Mbabaram (Dixon 1991) and Alawa (Sharpe 1972) allow final released Cs but ban final NCs. Neverver (Barbour 2012) bans final released Cs but allows final NCs; Wolof bans final released Cs but allows final released NCs[9]. Finally, the presence or absence of final NDs cannot be attributed to restrictions on final voiced obstruents. Wolof (Ka 1994), Boukhou Saafi (Mbodj 1983), and Basáa (Hyman 2001) allow final NDs but not Ds. Jabêm (Bradshaw & Czobor 2005) allows final Ds but not NDs.

Several of these points are discussed more fully in the context of the proposed analysis. While the distribution of NCs might appear to be linked to other, more general, phonotactic restrictions, the wide variety of patterns cited above suggest that these links are not causal. Restrictions on final NCs look superficially similar to restrictions on final Ds and final clusters because the final N*NC

[9]These facts show that the link between final release and the presence of NCs is not causal, contra Steriade (1993).

contrast, like laryngeal and simpleton-cluster contrasts (see Steriade 1997, Katzir Cozier 2008), is mostly dependent on release-associated cues.

### 3.2 N*NC: constraints and analysis

The analyses proposed here are in the framework of Dispersion Theory (Flemming 2002)[10] . I work within a contrast-based framework because contextual neutralization is better analyzed as the suspension of contrast rather than distributional restrictions targeting individual segments. Evidence for this comes from languages in which neutralization results in free variation (see Steriade 1994, Flemming 2002: 40-41, Flemming 2004). One such case is Gooniyandi (McGregor 1990), where a retroflex-apical stop contrast is permitted postvocalically but neutralized elsewhere. In contexts of neutralization, retroflex and alveolar stops are in free variation. This pattern and others cannot be analyzed by appealing to restrictions on the syntagmatic distribution of feature values; they must be analyzed by appealing to restrictions on the distribution of contrasts.

Beddor & Onsuwan's (2003) study highlights two important cues to the N*NC contrast: a difference in nasal vs. oral CV transitions (Δ CV transitions), and the presence vs. absence of an oral closure and release burst (Δ burst). While there very well may be other important cues to the N*NC contrast (e.g. Δ V1 duration, Δ N duration), this analysis focus only those cues that have been verified experimentally. I start with the hypothesis that the minimum acoustic distance necessary for reliable distinction of Ns and NCs is the presence of one of these cues (13).

(13) MINDIST N*NC (Δ BURST OR Δ CV TRANS): assign one violation for every N*NC pair in the output that does not differ in Δ burst or Δ CV transitions.

The MINDIST constant in (13), Δ BURST OR Δ CV TRANS, is violated when NCs are unreleased and the appropriate CV transitions are absent. The presence of one cue satisfies the constraint.

We know that some languages place more restrictive requirements on the N*NC contrast. In Alawa (Sharpe 1972), for example, word-final stops are released but final N*NC contrasts are neutralized. Other languages instantiating this pattern are the San Francisco del Mar dialect of Huave (Kim 2008, non-affricated NCs only), Mbabaram (Dixon 1991), Muyang (Smith & Gravina 2010), Ngambay (Vandame 1963), and Sebikotane Saafi (Stanton 2012). In these languages, Δ burst is not sufficient; Δ CV transitions is necessary for N*NC to be licensed (14).

(14) MINDIST N*NC (Δ CV TRANS): assign one violation for every N*NC pair in the output that does not differ in Δ CV transitions.

The status of a final N*NC contrast depends on the relative ranking of Δ CV TRANS and MAXCONTRAST, the latter of which is a positively evaluated constraint favoring output candidate inventories with the most members. In languages where the N*NC contrast is licensed word-finally, MAXCONTRAST dominates ΔCV TRANS: the contrast is preserved in spite of the absence of Δ CV transitions. The crucial ranking necessary to generate a grammar in which the N*NC contrast is licensed both prevocalically and finally is given below (15). Illustrative tableaux follow[11].

[10]For other frameworks explicitly referencing contrast or developments on Flemming's (2002) model, see e.g. Łubowicz (2012) and Chiosáin & Padgett (2010).

[11]I do not derive all possible phonetic implementations of the winning candidates in this tableau or others as this would complicate the analysis significantly, in ways orthogonal to the issues at hand.

(15) Crucial ranking for permissive languages
MaxContrast >> ΔCV trans

(16) MaxContrast >> Δ CV trans: word-final contrast

| an*and | MaxContrast | Δ CV trans |
|---|---|---|
| ☞ a. an*and | 2 | * |
| b. an | 1! | |
| c. and | 1! | |

(17) MaxContrast >> Δ CV trans: prevocalic contrast

| anã*anda | MaxContrast | Δ CV trans |
|---|---|---|
| ☞ a. anã*anda | 2 | |
| b. ana*anda | 2 | *! |
| c. anã | 1! | |
| d. anda | 1! | |

For restrictive languagues, where prevocalic but not final N*NC is licensed, MaxContrast does not dominate Δ CV trans[12]. When CV transitions are absent, N*NC is neutralized. The result of N*NC neutralization is always N, due to a low-ranked markedness constraint penalizing NCs (*NC). A possible ranking for restrictive languages is in (18); illustrative tableaux follow.

(18) Possible ranking for restrictive languages
Δ CV trans >> MaxContrast >> *NC

(19) Δ CV trans >> MaxContrast: word-final N*NC neutralization

| an*and | Δ CV trans | MaxContrast | *NC |
|---|---|---|---|
| a. an*and | *! | 2 | * |
| ☞ b. an | | 1 | |
| c. and | | 1 | *! |

(20) Δ CV trans >> MaxContrast: prevocalic N*NC contrast

| anã*anda | Δ CV trans | MaxContrast | *NC |
|---|---|---|---|
| ☞ a. anã*anda | | 2 | * |
| b. anã | | 1! | |
| c. anda | | 1! | * |

Across morpheme boundaries, the ranking in (18) predicts alternations, as seen in Sebikotane Saafi (Stanton 2012) (21) and Huave (San Francisco del Mar, Kim 2008) (22)[13]. Root-final NCs only surface as such when followed by a vowel-initial suffix.

[12]For languages in which final stops are released, we know that Δ CV trans >> MaxContrast, as transitions are necessary to license N*NC even when Δ burst would be present. In languages where final stops aren't released, it's difficult to determine the ranking between Δ CV trans and MaxContrast: the oral component of an unreleased NC may not be perceptible, meaning the N*NC contrast would violate Δ burst or Δ CV trans as well.

[13]Huave is classified as permissive: this dialect allows final N*NC for NC affricates, and some speakers preserve final N*NC for plain NCs (Kim 2008, p.c.). The San Mateo dialect always allows final N*NC (Kim 2008: 69, Noyer 2013).

(21) N*NC alternations in Saafi (Stanton 2012)

a. am → amb-i ('to help' → 'helped')

b. tiːn → tiːnd-en ('to walk' → 'walked')

(22) N*NC alternations in Huave (Kim 2008: 69)

a. t-a-jim → t-a-jimb-iuf ('she sweeps' → 'they go')

b. n-a-ion → n-a-iond-an ('(that) we endure it' → '(that) we endure it')

No ranking of the constraints introduced in this section – Δ BURST OR Δ CV TRANS, Δ CV TRANS, MAXCONTRAST, and *NC – generates a system where N*NC is licensed finally only (see Appendix C). As systems licensing N*NC finally only are unattested, this is a desirable result.

### 3.3 An alternative: burst amplitude and language-specific phonetics

An alternative interpretation of the difference between the restrictive and permissive languages in §3.1 could be the following: the two groups do not differ according to how important it is to maintain a certain perceptual distance between N and NC (as claimed above), but rather as a function of how perceptually distinct Ns and NCs are. It could be the case, for example, that word-final stop releases are longer and louder in some of the surveyed languages than in others. Assuming that this acoustic difference would lead to Δ burst being greater in languages where the release is more acoustically salient, the strength of the internal cues to N*NC will then differ across languages.

Cross-linguistic phonetic differences of the type sketched above have the potential to influence phonological patterning. In languages where stop releases are quieter, Δ burst on its own might not be sufficient to license N*NC, and word-final neutralization could result. In languages where stop releases are louder, Δ burst on its own might be sufficient to license N*NC, and the contrast could be maintained word-finally. Making a couple of additional assumptions, we can implement this analysis in a Dispersion Theoretic framework. The scale below (23) classifies N*NC contrasts into three categories, according to the strength of NC's release. When NCs are unreleased, Δ burst = 0; when NCs are quietly released, Δ burst = 1; when NCs are loudly released, Δ burst = 2[14].

(23) Release burst scale

0 N*NC˺ (unreleased NC)

1 N*NC$_1$ (quietly released NC)

2 N*NC$_2$ (loudly released NC)

To license word-final contrasts between Ns and loudly released NCs, but not Ns and quietly released NCs, a modification of the disjunctive constraint proposed in (13) is necessary. The revised definition in (24) requires N*NC contrasts to be cued by either Δ CV transitions or Δ burst of 2.

(24) MINDIST N*NC (Δ BURST (2) OR Δ CV TRANS): assign one violation for every N*NC pair in the output that does not differ in Δ burst of 2 or Δ CV transitions.

To satisfy (24), word-final N*NC contrasting pairs must differ in Δ burst by 2, according to the scale in (23). In languages with quietly released final NCs, (24) is not satisfied; the internal cues to

[14] I assume that the degree of release is modulated by additional constraints on articulatory effort, i.e. *VERYRELEASED, *RELEASED. For simplicity, I do not derive these differences in the tableaux that follow.

N*NC are insufficient, and the contrast is neutralized (25). In languages with loudly released NCs, Δ burst is sufficient; the word-final contrast is maintained (26).

(25) Neutralization of word-final N*NC when NCs are quietly released

| an*and | Δ BURST (2) OR Δ CV TRANS | MAXCONTRAST | *NC |
|---|---|---|---|
| a. an*and$_1$ | *! | 2 | * |
| ☞ b. an | | 1 | |
| c. and$_1$ | | 1 | *! |

(26) Preservation of word-final N*NC when NCs are loudly released

| an*and | Δ BURST (2) OR Δ CV TRANS | MAXCONTRAST | *NC |
|---|---|---|---|
| ☞ a. an*and$_2$ | | 2 | * |
| b. an | | 1! | |
| c. and$_2$ | | 1! | * |

The tableaux above provide an example of how the typology in §3.1 could be analyzed by appealing to language-specific differences in stop release quality, rather than differences in the ranking of Δ CV TRANS and MAXCONTRAST (as in §3.2). There is in fact independent evidence that appealing to the role of language-specific phonetic detail, i.e. salience of the release, is necessary in the analysis of the complete N*NC typology. In Huave (San Francisco del Mar; Kim 2008), for example, word-final contrasts between Ns and plain NCs (e.g. [m*mb]) are neutralized, but final contrasts between Ns and NC affricates (e.g. [n*nts]) survive. This difference between affricated and plain NCs can probably be attributed to the increased salience of the consonantal release: affricated releases are typically longer and louder than plain stop releases (see e.g. Wright 2004), rendering the internal cues to the affricated N*NC contrast more robust.

Because acoustic and perceptual studies of the surveyed languages appear to be nonexistent, however, and noncontrastive phonetic properties like stop releases are often not discussed in descriptive grammars, it is difficult to explore this alternative any further. This lack of information regarding language-specific phonetic detail is my primary motivation for not pursuing an analysis along these lines. While it is very likely that the phonetic correlates of the N*NC contrast differ on a language-specific basis, this has not been documented in any detail, and any link in this domain between differences in phonetic implementation and phonotactic restrictions has yet to be found.

It is important to note that, while the analyses sketched here and in §3.2 make different assumptions, they do not lead to different overall conclusions. Recall that the goals of the paper are twofold: (1) to document cross-linguistic restrictions on the distribution of NCs, and (2) to identify the nature of the constraints that regulate this distribution. Whether we analyze the cross-linguistic variation as a result of language-specific requirements on contrast distinctiveness, or as a result of language-specific differences in the perceptual space, both analyses make crucial reference to the role of contrast in phonology. Whichever story is true, the major claim of the paper still stands: *constraints regulating the distribution of NCs are constraints on contrast*.

### 3.4 On Δ burst and releases

In Lolovoli, a dialect of East Ambae, apocope targets word-final vowels (Hyslop 2001: 39-42). The frequency of apocope varies by speaker and by word, but there are consistent generalizations regarding the contexts in which apocope applies. I focus on the behavior of vowels following Ns, Ts, and NDs: vowels following Ns and Ts can delete, but vowels following NDs cannot (27).

(27) Apocope in Lolovoli (Hyslop 2001: 39-40)

| | | | |
|---|---|---|---|
| a. | man | ‘laugh’ | <mana> |
| b. | k$^{h}$at̪˺ | ‘speak’ | <gato> |
| c. | ma$^{n}$da | ‘rotten’ | <mada> |

Why does an apocope process targeting Ns and Ts not target NDs? A clue comes from the fact that word-final stops in Lolovoli are unreleased (Hyslop 2001: 30). Bans on word-final releases usually apply to all stops: languages in which plain oral stops can’t be released, but NCs can, are rare[15]. If apocope applied post-NC, the resulting final NCs would likely be unreleased.

As discussed in §2.1, Δ burst and Δ CV transitions are likely two of the major cues to the N*ND contrast. Neither cue is available when final NDs are unreleased. A possible interpretation of the pattern in (27) is that speakers do not delete post-NC vowels because doing so would jeopardize the N*NC contrast. In other words, preserving the N*NC contrast is more important than apocope.

To formalize this compromise, two new constraints are necessary. *R# penalizes all word-final releases (28), and *V# penalizes all words ending in a vowel (29).

(28) *R#: assign one violation for each released stop in the output.

(29) *V#: assign one violation for each candidate ending in a vowel.

Because all word-final stops are unreleased, we know that *R# is undominated in Lolovoli. As the desire to maintain a sufficiently distinct contrast between N and NC takes priority over apocope, we know that both Δ Burst or Δ CV trans and MaxContrast dominate *V#. A summary of the ranking arguments necessary to generate (27) is below; an illustrative tableau follows.

(30) Necessary ranking arguments for Lolovoli

Δ Burst or Δ CV trans    *R#    MaxContrast

*V#

(31) Lolovoli: apocope post-N, but not post-NC

| anã*anda | *R# | Δ Burst or Δ CV trans | MaxContrast | *V# |
|---|---|---|---|---|
| ☞ a. an*anda | | | 2 | * |
| b. an*and | *! | | 2 | |
| c. anã*and˺ | | *! | 2 | |
| d. an*and˺ | | *! | 2 | |
| e. anã*anda | | | 2 | **! |
| f. an | | | 1! | |

[15] One exception is Wolof, where final plain Cs aren’t released, but geminates and NCs are. See <http://archive.phonetics.ucla.edu/Language/WOL/wol.html> for recordings. Another case is Boukhou Saafi (Mbodj 1983), where it appears that NCs but not single Cs are released after long vowels. Also, in South Efate (Thieberger 2006), word-final /$^{n}$d$^{r}$/ (a prenasalized alveolar stop with a trilled release) is released, even though final Cs and Ns are unreleased. But it is unclear whether /$^{n}$d$^{r}$/ is released simply by virtue of being an NC, or because trills are permitted word-finally and /$^{n}$d$^{r}$/ is, after all, half-trill. I am unaware of further cases where the release differentiates Cs and NCs.

Candidate B is eliminated due to a fatal violation of *R#, as the final stop in [and] is released. Candidates C and D are eliminated due to fatal violations of $\Delta$ BURST OR $\Delta$ CV TRANS, as the final stops are unreleased and Ns and NCs do not differ in the appropriate CV transitions. Candidate E is eliminated due to an unnecessary violation of *V#, and Candidate F, the neutralizing candidate, is eliminated by MAXCONTRAST. Candidate A emerges as the winner, as it is the unique candidate that best satisfies *V# while keeping the N*NC contrast sufficiently distinct.

The importance of $\Delta$ burst to final N*ND is not just evident in Lolovoli. Languages that ban final released stops tend to ban final NCs; for word-final NDs, this generalization is absolute[16]. Steriade (1993), in an effort to explain Feinstein's (1979) generalization that final NCs are cross-linguistically rare, proposes that NCs will not surface word-finally if word-final stops are unreleased. Her proposal is based on the representation of NCs as bipositional stops, with [nasal] associated exclusively to the closure. When NC's release is absent, NC is featurally identical to N, so a contrast between N and NC will not survive. My account makes a different claim: what distinguishes NC from N is not the presence vs. absence of an oral release, but rather a collection of perceptual cues (e.g. burst amplitude, CV transitions, N duration especially for N*NT). The loss of NC's release does not entail the loss of the N*NC contrast; it's just that many of the cues to the N*NC contrast are release-associated. When NC's final release is lost, many of the cues to N*NC go with it.

An empirical problem for Steriade's proposal is that the status of final stop releases does not correlate directly with the status of final NCs (see also §3.1). Alawa and Mbabaram show that languages with final released stops can still ban final NCs. Under the present account, the analysis of these restrictive languages is straightforward. The presence of $\Delta$ CV transitions is necessary to license the N*NC contrast; $\Delta$ burst is not enough ($\Delta$ CV TRANS >> MAXCONTRAST). In addition, there is a potential system in which final NTs are unreleased, but final N*NT is maintained. Barbour's (2012) description of Neverver suggests that there is a class of speakers for whom a final N*NT contrast is licensed despite the fact that all Cs, even NTs, are unreleased.

The retention of a final N*NT contrast despite the lack of an oral release could be attributed to the fact that N*NT contrasts are likely bolstered by non-release-associated cues (e.g. large difference in N duration, difference in V1 duration; see §2.1). It is likely that the N*NT contrast in Neverver is marked by one of these additional cues, allowing it to be maintained when $\Delta$ CV transitions are absent[17]. But this is speculation, as there is no phonetic information available.

### 3.5 Contrast enhancement: final ND devoicing

In a number of systems, a prevocalic N*ND contrast is (or can be) realized word-finally as N*NT. Languages with obligatory ND devoicing include Neverver (Barbour 2012), Kobon (Davies 1980), and Naman (Crowley 2006b) (see (32)). Languages with optional devoicing include Avava (Crowley

[16] Some relevant cases include Acehnese (Durie 1985), Lua (Boyeldieu 1985), Gbaya Kara (Monino & Roulon 1972), Vouté (Guarisma 1978), and Wembawemba (Hercus 1986).

[17] An anonymous reviewer correctly notes that the possibility for word-final N*NC to be retained when final NC is unreleased undermines somewhat the analysis of Lolovoli in this section. They suggest that if it is possible for a final N*NC contrast to be maintained in the absence of $\Delta$ burst and $\Delta$ CV transitions, then perhaps the reason why post-NC stops fail to apocopate is due to a more pressing need for $\Delta$ CV transitions. This is a possible alternative – but in this situation we might expect for post-N vowels to also resist apocope, as for the contrast to be maximally distinct, NC must be followed by oral transitions *and N must be followed by nasal transitions*. In addition, it is a fact across the surveyed languages that only N*NT (and not N*ND) contrasts survive when final NC is unreleased. Because Lolovoli has only NDs, I believe it is likely that the lack of a burst is the true culprit here.

2006a), Páez (Rojas Curieux 1998), and Tape (Crowley 2006c)[18] (see (33)).

(32) Optional ND devoicing in Tape (Crowley 2006c: 101)

a. $\text{mi}^{\text{m}}\text{b} \sim \text{mi}^{\text{m}}\text{p}$ 'gecko'
b. $\text{imimi}^{\text{n}}\text{d} \sim \text{imimi}^{\text{n}}\text{t}$ '(s)he is sweating'

(33) Obligatory devoicing in Kobon (Davies 1980: 24)

a. $\text{gamp}^{\text{h}}$ 'he does' <gab>
b. $\text{yant}^{\text{h}}$ 'I' <yad>

A possible – but likely incorrect – explanation for this phenomenon is that NDs in these languages are phonetically enhanced underlying Ds, and that devoicing results from a more general restriction on final voiced obstruents. But if this were the case, we would expect for the outcome of devoicing to be [T], not [NT], as there is no reason for a voicing enhancement to accompany a devoiced stop. In addition, it has already been established that the presence or absence of final NDs is not causally linked the status of final voiced obstruents (§3.1): there are languages allowing final NDs but not Ds (e.g. Wolof), and languages allowing final Ds but not NDs (e.g. Jabêm).

An alternative explanation for ND devoicing is necessary. From an articulatory perspective, such an explanation is not immediately obvious. NTs are thought to be more articulatorily complex than are NDs, as the production of NTs requires precise gestural coordination between the velum and the glottis[19]. The velum must raise quickly after voicing ceases in order for the oral closure to be fully voiceless. NT sequences are actively avoided and even eliminated in a number of languages (see Pater 1999, 2001 for a discussion of *NT effects in Austronesian), and this conspiracy is hypothesized to have an articulatory basis. If NTs are universally marked, why are we seeing evidence of a pattern in multiple unrelated languages that creates them, only in word-final position?

These two questions receive straightforward perceptual answers. Perhaps speakers expend additional articulatory effort to enhance N*ND when Δ CV transitions is absent. N*NT is presumably more robust than is N*ND because it is marked by more salient acoustic properties (e.g. difference in N duration, potential difference in V1 duration, larger difference in burst amplitude; see §2.1[20]). A potential reason why ND devoicing happens finally (and only finally) in these languages is that in this position, Δ CV transitions is absent. The idea is that speakers expend additional articulatory effort to render N*ND more distinct only when cues to the contrast are compromised[21].

In languages with variable ND devoicing, we can say that two opposing pressures conflict: the need for more perceptible contrasts (resulting in N*NT) and avoidance of articulatory effort (resulting in N*ND). The result is variation between a contrast that is less perceptible but comparatively easy, and a contrast that is more perceptible but harder to implement. In languages where N*ND is

[18]None of these languages have phonemic Ds or NTs; their stop inventories include only Ts, NDs, and Ns. For more information about the stop inventories of all surveyed languages, see Appendix A.

[19]Although final devoicing is thought to be phonetically natural (see Westbury & Keating 1986), it's not clear that final devoicing is phonetically natural for Ds preceded by Ns. In post-nasal contexts, obstruent voicing is facilitated, and languages without categorical post-nasal voicing (e.g. English) can exhibit gradient effects (Hayes & Stivers 2000). In at least some languages, gradient post-nasal voicing occurs word-finally. A phonetic study of two Romanian speakers reveals a significant word-final post-nasal voicing effect (Steriade & Zhang 2001

[20]I do not know whether or not the devoiced NDs in these languages have the phonetic properties attributed to NTs.

[21]An anonymous reviewer wonders if enhancing the N*ND contrast through devoicing to N*NT compromises in any way the final T*NT contrast. It might: if so, an additional component of the analysis then has to be that maintaining N*NC is more important than keeping C*NC maximally distinct. See §4.3 for more on N*NC & C*NC interactions.

maintained without enhancement word-finally, speakers just prefer to avoid NTs altogether.

The analysis of final NC effects presented in this section offers an alternative explanation for Hyman's (2001) observation that, in some languages, N+D sequences at a morphological boundary either undergo D-nasalization or post-nasal devoicing. While Hyman proposes that *ND is an active constraint, I interpret these processes as resulting from constraints on the contrast between N and ND. D-nasalization is neutralization, and post-nasal devoicing is enhancement. While the languages highlighted by Hyman are somewhat unusual in that N*ND neutralization and enhancement occur pre-vocalically, these facts alone are not problematic for this analysis. What the present analysis predicts is that if ND devoicing or neutralization occurs pre-vocalically (where $\Delta$ CV transitions is present), it will also occur word-finally (where $\Delta$ CV transitions is absent). The languages discussed by Hyman (2001) do not allow final Cs, and do not bear one way or the other on this prediction.

# 4 Initial NCs and the C*NC contrast

The survey results verify the prediction in (11): initial C*NC asymmetrically implies postvocalic C*NC. §4.1 presents the results of the survey and discusses two apparent counterexamples; §4.2 presents an analysis of the typology. §4.3 discusses cases of variation that point to an interaction between the N*NC and C*NC contrasts.

## 4.1 Survey results

Of the 50 languages surveyed, 42 languages license initial and postvocalic C*NC, 6 languages license postvocalic C*NC only, and 2 languages license initial C*NC only. Languages licensing C*NC postvocalically and initially (✓V_V, ✓#_V) are 'permissive,' and languages licensing C*NC postvocalically only (✓V_V, *#_V) are 'restrictive'. The languages classified as 'other' allow C*NC initially only (*V_V, ✓#_V). Examples are below (34); see Appendix A for a full listing.

(34) Results for C*NC contrast

| Permissive (✓V_V, ✓#_V) | Restrictive (✓V_V, *#_V) | Other (*V_V, ✓#_V) |
|---|---|---|
| *42 languages, e.g.*<br>Akoose (Hedinger 2008)<br>Erromangan (Crowley 1990)<br>Ngambay (Vandame 1963) | *6 languages, e.g.*<br>Kobon (Davies 1980)<br>Mani (Childs 2011)<br>Sinhalese (Feinstein 1979) | *2 languages*<br>Lua (Boyeldieu 1985)<br>Mbum (Hagège 1970) |

Note that the six restrictive languages – Jabêm (Bradshaw & Czobor 2005), Kobon (Davies 1980), Mani (Childs 2011), Sinhalese (Feinstein 1979), Wembawemba (Hercus 1986)[22] and Zarma (Tersis 1972) – are all languages that allow voiced stops in initial position[23]. Put differently, *no languages* with only voiceless stops in initial position neutralize initial C*NC. This is expected, as contrasts where C and NC share the same value for [±voice] (i.e. D*ND) are presumably more confusable than contrasts where they do not (i.e. T*ND). The fact that initial C*NC is neutralized only when C and NC agree in [±voice] is consistent with the view that contrasts are neutralized in positions where they are most confusable. While there are other languages in which NDs are

[22] All except Wembawemba license a phonemic contrast between voiced and voiceless stops. In Wembawemba, stops are generally voiceless, but in initial position, "there are exceptions" and "devoicing is only partial" (Hercus 1986: 6).

[23] See Appendix A for more information about the stop inventories in all surveyed languages.

variably realized as Ds, i.e. Lolovoli (Hyslop 2001), Páez (Rojas Curieux 1998), and Tape (Crowley 2006c), these are languages in which plain Ds are absent, so the variation between initial ND and D is not neutralization, but likely just variation among possible ways to implement the C*NC contrast.

The languages licensing only initial C*NC, Lua and Mbum, are problems for the prediction in (11). Languages licensing postvocalic C*NC only are expected to exist, but languages licensing initial C*NC only are not. When we look more closely at the distribution of initial vs. intervocalic consonants in Lua (35)[24], however, it becomes clear that the C*NC contrast is only one of many contrasts neutralized intervocalically. Below, parentheses indicate low frequency.

(35) Initial vs. intervocalic Cs in Lua (Boyeldieu 1985: 65, 74)

| **Consonant type** | **Initial** | | | | **Intervocalic** | | | |
|---|---|---|---|---|---|---|---|---|
| *Voiceless stops* | p | t | c | k | | | | |
| *Voiced stops* | b | d | ɟ | g | b | d | ɟ | g |
| *Glottals* | ɓ | ɗ | | ʔ | | | | |
| *Fricatives* | | s | | h | | | | |
| *Prenasalized stops* | mb | nd | ɲɟ | ŋg | | | | ŋg |
| *Nasals* | m w̃ | n | ɲ | | m | n | | (ŋ) |
| *Approximants/glides* | w | l | j | | | l | | |
| *Trills* | | r | | | | r | | |

We can hypothesize that the source of these intervocalic restrictions is a significant durational asymmetry between the word-initial syllable and all others, related to the presence of an initial accent at some point in the language's history (Boyeldieu 1985: 255ff). Generally speaking, voiced and voiceless obstruents are differentiated by closure duration, with longer duration cuing voicelessness (Massaro & Cohen 1983). In Lua, the T*D contrast is licensed in initial position, but neutralized elsewhere in favor of the shorter D. In addition, the fricatives /s/ and /h/ are present in initial position, but entirely absent in intervocalic position (except for a few recent loans). Since fricatives are relatively long (Wright 2004: 37), their absence in intervocalic position is consistent with a durational restriction. Additional support for this hypothesis comes from positional restrictions on vowel contrasts in Lua. While word-initial syllables license a large number of vowel contrasts, the inventory is quite restricted in all other syllables (see Boyeldieu 1985: 136 for initial syllables, and 146 for all others). For example, contrasts in length and nasality are licensed in initial position but not elsewhere; the cues to both of these contrasts are weakened when vocalic duration is reduced (see Whalen & Beddor 1989 on the link between nasality and duration). Contour tones, which tend to require long hosts (Zhang 2002), are also permitted in initial syllables but not elsewhere.

The absence of an intervocalic C*NC contrast in Lua is clearly due to factors broader than perception of the C*NC contrast alone. Although phonetic data is not available, we can speculate that the loss of NCs in intervocalic position is not due to diminished perceptibility of C*NC, but rather N*NC: if the following vowel is too short to host Δ CV transitions of the appropriate duration, cues to the N*NC contrast in this position would potentially be compromised.

In Mbum, we find many of the same positional restrictions. For example, as in Lua, laryngeal contrasts are neutralized and fricatives are banned in all but initial position (36). The vowel inventory of Mbum, too, is significantly reduced in all non-initial syllables. In initial syllables Mbum has a standard five-vowel inventory (/i/, /e/, /a/, /o/, /u/) as well as three peripheral nasal vowels

[24] I include only medial Cs attested in the native lexicon. See Boyeldieu for a description of loanword phonology.

(/ĩ/, /ã/, /ũ/). In non-initial syllables, the oral vowel inventory is reduced to /i/, /a/, /u/, and nasal vowels are absent altogether (Hagège 1970: 57, 60-61). Hagège does not discuss a possible source of the asymmetries, but these restrictions look very similar to the ones encountered in Lua, and are consistent with a story where the initial syllable is lengthened and all others are reduced[25].

(36) Initial vs. intervocalic Cs in Mbum (Hagège 1970: 55)

| **Consonant type** | **Initial** | | | | | | | **Intervocalic** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Voiceless stops* | p | | t | | k | kp | | (p) | t | | k | |
| *Voiced stops* | b | b̪ | d | | g | gb | | (b) | | | | |
| *Voiceless fricatives* | | f | | s | | | | | | | | |
| *Voiced fricatives* | | v | | z | | | | | | | | |
| *Prenasalized stops* | mb | | nd | | ŋg | ŋgb | | | | | (ŋg) | |
| *Prenasailzed affricates* | | mv | | nz | | | | | | | | |
| *Implosives* | ɓ | | ɗ | | | | | | | | | |
| *Nasals* | m | | n | ɲ | | | | (m) | (n) | | (ŋ) | |
| *Approximants/glides* | | | l | j | | w | h | | l | j | | w |
| *Trills* | | | r | | | | | | r | | | |

Comparison of the N*NC survey results (§3.1) with the C*NC results reveals an additional asymmetry. While a large majority of the languages allow initial C*NC (44/50), fewer languages allow final N*NC (19/50). This asymmetry is extremely significant (Fisher's exact, $p < .0001$), and correlates with Beddor & Onsuwan's (2003) results. For the Ikalanga speakers in their study, N*NC is primarily dependent on Δ CV transitions; in the survey, most languages neutralize N*NC word-finally, where Δ CV transitions is absent. By contrast, their results indicate that C*NC is less dependent on Δ VC transitions; in the survey, most languages maintain initial C*NC despite the absence of Δ VC transitions. The observed difference in cue distribution between the two contrasts is directly reflected in the asymmetry of neutralization patterns documented here.

## 4.2 C*NC: constraints and analysis

The analysis of the C*NC typology is identical in spirit to the analysis of the N*NC typology in §3.2. The two experimentally verified cues to the C*NC contrast are Δ nasal formants and Δ VC transitions; we will hypothesize that C*NC contrasts that share the same value for [±voice] require the presence of one or the other of these cues (37).

(37) MINDIST C*NC (Δ NASAL F OR Δ VC TRANS): assign one violation for every [$\alpha$voice] C*NC pair in the output that is not cued by Δ nasal formants or Δ VC transitions.

Δ NASAL F OR Δ VC TRANS is only violated when NCs lack a nasal onset and the appropriate VC transitions are absent. Satisfaction of one disjunct is enough to satisfy the entire constraint; the presence of either Δ nasal formants or Δ VC transitions is sufficient.

Some languages place more restrictive requirements on the C*NC contrast. In Sinhala (Feinstein 1979) and Kobon (Davies 1980), for example, initial C*NC is not licensed. In the restrictive languages, we can hypothesize that Δ VC transitions is an obligatory cue to the contrast (38).

[25] To the best of my knowledge, Lua and Mbum are the only two languages in the survey with initial vs. intervocalic asymmetries of this magnitude. Many languages in the survey in fact exhibit the opposite pattern: they license more contrasts in intervocalic than initial position.

(38) MINDIST C*NC (Δ VC TRANS): assign one violation for every [$\alpha$voice] C*NC pair in the output that is not cued by Δ VC transitions.

The status of initial C*NC depends on the relative ranking of Δ VC TRANS and MAXCONTRAST. For the permissive languages, MAXCONTRAST dominates Δ VC TRANS, as the presence of Δ VC transitions is not necessary for C*NC to be licensed (39). Illustrative tableau follow.

(39) Crucial ranking for permissive languages
MAXCONTRAST >> Δ VC TRANS

(40) MAXCONTRAST >> Δ VC TRANS: word-initial C*NC contrast licensed

| da*nda | MAXCONTRAST | Δ VC TRANS |
|---|---|---|
| ☞ a. da*nda | 2 | * |
| b. da | 1! | |
| c. nda | 1! | |

(41) MAXCONTRAST >> Δ VC TRANS: postvocalic C*NC contrast licensed

| ada*ãnda | MAXCONTRAST | Δ VC TRANS |
|---|---|---|
| ☞ a. ada*ãnda | 2 | |
| b. ada | 1! | |
| c. ãnda | 1! | |

In the restrictive languages, where C*NC is licensed postvocalically but not initially, Δ VC TRANS dominates MAXCONTRAST. The result of C*NC neutralization is always C, due to low-ranked *NC. The ranking for the restrictive systems is below (42); tableaux follow.

(42) Crucial ranking for restrictive languages
Δ VC TRANS >> MAXCONTRAST >> *NC

(43) Δ VC TRANS >> MAXCONTRAST: word-initial C*NC neutralized

| da*nda | Δ VC TRANS | MAXCONTRAST | *NC |
|---|---|---|---|
| a. da*nda | *! | 2 | * |
| ☞ b. da | | 1 | |
| c. nda | | 1 | *! |

(44) Δ VC TRANS >> MAXCONTRAST: postvocalic C*NC contrast licensed

| ada*ãnda | Δ VC TRANS | MAXCONTRAST | *NC |
|---|---|---|---|
| ☞ a. ada*ãnda | | 2 | * |
| b. ada | | 1! | |
| c. ãnda | | 1! | * |

No permutation of these constraints can generate a system in which C*NC is licensed initially only (see Appendix C). This is a desirable prediction, as systems of this type, not amenable to an alternative analysis, are unattested[26].

[26] Analyses for Lua and Mbum would assume that they are permissive languages (MAXCONTRAST >> Δ VC TRANS). The absence of intervocalic NCs is ultimately due to constraints motivating reduction, which outrank MAXCONTRAST (REDUCE! >> MAXCONTRAST). The precise formulation of these additional constraints is not explored here.

As was discussed in relation to the N*NC contrast in §3.3, it is possible that the relevant difference between the permissive and the restrictive C*NC systems is one of language-specific differences in the perceptual space, rather than differences in the required distance between contrasting segments. For example, in some of the restrictive systems, pre-NC vowels could be heavily nasalized, and speakers would rely on Δ VC transitions to cue the C*NC contrast (see §4.3). In these cases, C*NC might be neutralized word-initially, where Δ VC transitions is absent. It could also be that in some of the permissive systems, pre-NC vowels are lightly nasalized (or not nasalized at all). In these languages, the perceptibility of C*NC would likely be only marginally impacted by the absence of Δ VC transitions, and the contrast could be maintained word-initially as a result.

Again, however, the phonetic data necessary to draw such a correlation are not available: we do not know how the acoustic and perceptual correlates to C*NC vary across the surveyed languages. And again, even if further work demonstrates that the factors responsible for the difference between permissive and restrictive C*NC languages is entirely due to language-specific differences in the perceptual space, the necessary revisions to the analysis would not in any way invalidate the major claim of this paper. Constraints on the distribution of NCs are constraints on contrast.

### 4.3 Variation and VC transitions

According to Vandame (1963: 33), intervocalic VNCV sequences in Ngambay are realized as either [anda] or [ãda] when the first vowel is /a/, /e/, or /o/; tones are omitted in (45)[27].

(45) VNC ~ ṼC variation in Ngambay (Vandame 1963: 33, translations mine)
   a. andə ~ ãdə 'he enters'
   b. konde ~ kõde 'harp'

This variation points to the importance of transitional cues in maintenance of the C*NC contrast. NCs can be phonetically realized as Cs, provided nasal VC transitions are present to allow the listener to distinguish Cs from NCs. The variation also points to a potential interaction between the N*NC and C*NC contrasts. The [ãda] variant maximizes distinctiveness of the N*NC contrast (Δ ãna*ãda > Δ ãna*ãnda), at the cost of rendering the C*NC contrast less distinct (Δ ada*ãda < Δ ada*ãnda). The [ãnda] variant maximizes distinctiveness of the C*NC contrast (Δ ada*ãnda > Δ ada*ãda) at the expense of rendering the N*NC contrast less distinct (Δ ãna*ãnda < Δ ãna*ãda). What is crucial is that the variation between C and NC in (45) is only attested intervocalically, where all cues to both C*NC and C*NC are, in principle, available.

A similar pattern is found in Tukang Besi (Donohue 1999). The prenasalized affricate, /ns/, has two allophonic variants. The first is a faithful realization with an oral closure, [ntʃ][28]. The second variant, a plain [s] preceded by a nasal vowel, is more common (46).

(46) Variation in Tukang Besi (Donohue 1999:29)
   ma$^{n}$sa ~ mãsa   'silat (fighting arts)'

[27] Pre-NC vowels are not marked as nasalized in these examples, but Vandame asserts elsewhere (p. 33) that pre-NC vowels are significantly nasalized.

[28] There is no contrast in Tukang Besi between prenasalized affricates and prenasalized fricatives, nor is such a contrast attested in any language (see Steriade 1993). In Tukang Besi, /ns/ is usually pronounced with an oral occlusion.

/s/ is possible word-initially, but /ns/ is not. Donohue speculates that this restriction on the distribution of /ns/ can be attributed to the "lack of a preceding vowel in word-initial position" (Donohue 1999: 29). Reframed slightly, Donohue's speculation is that /s/ and /ns/ are not contrastive word-initially because the most reliable cue to the contrast, Δ VC transitions, is absent in this position.

Additional diachronic evidence suggests that C*NC is unstable initially, in precisely the context where VC transitions are absent. In Wolof (Ka 1994), while D*ND is licensed initially and postvocalically, T*NT is licensed only postvocalically. Ka's explanation for the lack of initial NTs is that they have lost their prenasalization and turned into voiceless stops. This D*ND vs. T*NT asymmetry receives a straightforward perceptual explanation. The nasal portion of NDs comprises a majority of the total segmental duration, but the nasal portion of NTs is much shorter, taking up on average half of the total duration (see §2.1 for references). Beddor & Onsuwan's (2003) results suggest that as the duration of NC's nasal formants is reduced, reliable identification of NCs becomes more dependent on the presence of nasal VC transitions. Perhaps N*NT in Wolof was more dependent on Δ VC transitions than N*ND, and was lost initially as a result.

Both the Tukang Besi facts and the diachronic development in Wolof reflect the major theme of this section: a C*NC contrast is prone to neutralization word-initially, where VC transitions are absent. All else being equal, initial C*NC entails postvocalic C*NC.

# 5 Extending the predictions: segments vs. clusters

The major claim of the paper is that constraints on the distribution of NCs are constraints on contrast. But what if some of the languages in the survey are misclassified, and what I refer to as "prenasalized stops" are, in some systems, actually NC clusters? If we use different criteria for identifying unary NCs – by following Riehl's (2008: 15) decision tree, for example – do the conclusions change?

In this section, I argue that the answer to this last question is *no*. In §5.1, I show that, regardless of whether we adopt my strictly phonotactic classification scheme, or Riehl's more detailed decision tree, the implicational generalizations discovered above hold. In §5.2, I present the results of a small survey and show that the implicational relationship documented for the unary N*NC contrast holds also for languages where NCs are obviously clusters: final N*NC implies prevocalic N*NC, regardless of NC's phonological status. This is not a surprising result. As has been frequently documented in the literature, the phonological difference between NC segments and NC clusters does not contribute to a substantial difference in their phonetics (Maddieson & Ladefoged 1993, Ladefoged & Maddieson 1996; see also Riehl 2008, Cohn & Riehl 2012).

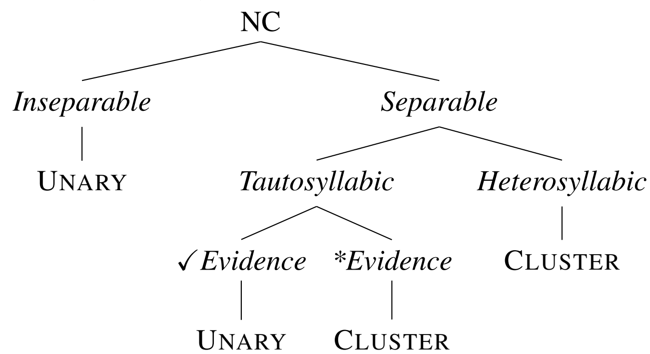
The main point of the section, then, is that it does not matter for our purposes whether NCs are segments or clusters. The same implicational generalizations hold.

## 5.1 Riehl (2008) and separability

Riehl (2008: 15) presents a method for classifying NCs as segments or clusters that differs somewhat from the diagnostic employed in the present paper. While I treat NCs as segments if they are licit in environments where other clusters (or sonority-violating clusters) are not, Riehl (2008: 15) advocates a three-step approach to determining the unary or cluster status of an NC sequence.

The first step in classifying a given NC sequence as a segment or a cluster is to determine whether or not the sequence is "separable". An NC sequence is said to be "separable" if both of its component parts occur independently. For example, in a language with both [m] and [b], the sequence [mb] is separable; in a language that has [m] but lacks [b], [mb] is inseparable. Riehl claims that inseparable NCs are necessarily unary. If the NC sequence is separable, the next step is to determine properties of its syllabification. If the NC sequence is heterosyllabic (i.e. am$_\sigma$ba$_\sigma$), it is a cluster; if it is tautosyllabic (i.e. a$_\sigma$mba$_\sigma$), it is a cluster unless there is independent evidence that the sequence is treated as a single segment by the phonology. The kinds of independent evidence that Riehl considers sufficient to postulate a unary analysis include pre-C lengthening phenomena (though cf. Downing 2005) and cluster phonotactics. The decision tree is replicated in (47).

(47) Riehl's (2008: 15) decision tree




The question, now, is the following: if we look more closely at the surveyed languages and classify them according to the decision tree in (47), does this study have the same conclusions?

To answer this question, I separated the surveyed languages into two categories: "obviously unary" and "not obviously unary". The first category, "obviously unary", consists of all languages in which at least one NC sequence is inseparable, and therefore unary, according to Riehl. The second category, "not obviously unary', consists of all languages in which all NC sequences are separable. I did not make further distinctions within this category, as it is unclear to me exactly how much evidence is necessary to postulate a unary analysis within Riehl's framework. 20 of the surveyed languages have at least one inseparable NC, while in the remaining 30, all NCs are separable. The surveyed languages are annotated with this information in Appendix A.

Looking at the patterns of N*NC neutralization, we find that the same implicational generalization holds across the "obviously unary" (48) and "not obviously unary" (49) groups. In both cases, final N*NC implies prevocalic N*NC. We do, however, find an interesting asymmetry between the two groups: most of the permissive languages fall into the "obviously unary" category, while most of the restrictive languages fall into the "not obviously unary" category. The sample size is small, but the asymmetry is significant (Fisher's exact, p = .016). Perhaps part of the reason why so many languages in the "not obviously unary" category are restrictive is that some of them are in fact languages with NC clusters, and the ban on final NCs is just part of a larger ban on final clusters.

(48) N*NC for languages with "obviously unary" NCs

| Permissive (✓_V, ✓V_#) | Restrictive (✓_V, *V_#) | Other (*_V, ✓V_#) |
|---|---|---|
| *12 languages, e.g.*<br>Avava (Crowley 2006a)<br>Naman (Crowley 2006b)<br>Páez (Rojas Curieux 1998) | *8 languages, e.g.*<br>Alawa (Sharpe 1972)<br>Kaulong (Ross 2002)<br>Lolovoli (Hyslop 2001) | *0 languages* |

(49) N*NC for languages with "not obviously unary" NCs

| Permissive (✓_V, ✓V_#) | Restrictive (✓_V, *V_#) | Other (*_V, ✓V_#) |
|---|---|---|
| *7 languages, e.g.* | *23 languages, e.g.* | *0 languages* |
| Kobon (Davies 1980) | Acehnese (Durie 1985) | |
| Makaa (Heath 2003) | Lua (Boyeldieu 1985) | |
| Tobati (Donohue 2002) | Ngambay (Vandame 1963) | |

For the C*NC contrast, too, the same implicational generalization holds across both groups of languages. For languages with inseparable NCs, postvocalic C*NC always implies initial C*NC; for languages with separable NCs, the same generalization holds, with the exceptions of Lua and Mbum (see §4.1). While slightly more "not obviously unary" than "obviously unary" languages are permissive, this is not a significant asymmetry (Fisher's exact, p = .38).

(50) C*NC for languages with "obviously unary" NCs

| Permissive (✓V_V, ✓#_V) | Restrictive (✓V_V, *#_V) | Other (*V_V, ✓#_V) |
|---|---|---|
| *19 languages, e.g.* | *1 language* | *0 languages* |
| Avava (Crowley 2006a) | Wembawemba (Hercus 1986) | |
| Basáa (Hyman 2001) | | |
| Lolovoli (Hyslop 2001) | | |

(51) C*NC for languages with "not obviously unary" NCs

| Permissive (✓V_V, ✓#_V) | Restrictive (✓V_V, *#_V) | Other (*V_V, ✓#_V) |
|---|---|---|
| *23 languages, e.g.* | *5 languages, e.g.* | *2 languages* |
| Akoose (Hedinger 2008) | Kobon (Davies 1980) | Lua (Boyeldieu 1985) |
| Gbeya (Samarin 1966) | Mani (Childs 2011) | Mbum (Hagège 1970) |
| Nizaa (Endresen 1991) | Sinhalese (Feinstein 1979) | |

In both the "obviously unary" and "not obviously unary" classes, more languages license initial C*NC than do final N*NC. This asymmetry is significant for both groups (Fisher's exact; $p = .019$ for "obviously unary"; $p < .001$ for "not obviously unary"). The picture that emerges from this exercise is that classifying the languages in the survey according to Riehl's decision tree does not impact the results or the conclusions of this study in any way. As far as the distributional properties of NCs go, whether they are "obviously unary" or "not obviously unary" does not matter.

## 5.2 Extending the survey: NC clusters

To further substantiate the claim that the distributional properties of NCs are not dependent on their phonological status, I conducted a small survey of languages in which NCs are undeniably clusters. The survey was not intended to be exhaustive or typologically balanced. A prerequisite for inclusion was that the language allow final sonorant-stop clusters, so that the absence of final NC is a significant gap. As none of the surveyed languages allow initial NCs, the prediction that postvocalic C*NC should imply initial C*NC is vacuously true. In all 25 languages surveyed, N*NC is licensed prevocalically; in 19, N*NC is also licensed word-finally. Examples are in (52); the full list in in Appendix A.

(52) N*NC in languages with clear NC clusters

| Permissive (✓_V, ✓V_#) | Restrictive (✓_V, *V_#) | Other (*_V, ✓V_#) |
|---|---|---|
| *19 languages, e.g.* | *6 languages, e.g.* | *0 languages* |
| Iraqw (Mous 1993) | Breton (Press 1987) | |
| Romanian (Chiţoran 2002) | Québec French (Côté 2000) | |
| Yiddish (Jacobs 2005) | Wardaman (Merlan 1994) | |

Note that in many of the permissive languages, the number of N*NC contrasts licensed word-finally is much smaller than than the number of N*NC contrasts licensed prevocalically. In American English, for example, while N*NT and N*ND are licensed prevocalically at all places of articulation, the only N*ND contrast licensed word-finally is /n*nd/ (✓[and], but *[amb], *[aŋg]). In Catalan (Côté 2004: 6 and references there), Québec French ((Côté 2000): 233), Trinidad English (Katzir Cozier 2008), Basque (Hualde & de Urbina 2003), and others, N*NT and N*ND are licensed prevocalically, but only N*NT is licensed word-finally. As expected, there are no cases in which an N*NC contrast is maintained word-finally but neutralized prevocalically. The implicational laws governing the distribution of NCs, whether segments or clusters, appear to be one and the same.

It is worth taking a step back, now, and asking *why* this is the case: why are the phonological differences between the different NC types not reflected in their distributional properties? The answer to this question is simple: phonological differences between different NC types aren't reflected in their distributional properties because they aren't reflected, for the most part, in the phonetics.

Many studies have demonstrated that NC segments and clusters are phonetically similar. For one, the relative timing of the N and C components is consistent irrespective of the representational status of NCs (see e.g. Cohn 1990, Riehl 2008, Cohn & Riehl 2012). All ND sequences, regardless of whether they are analyzed as segments or clusters, have a long N and a short D. For both segment and cluster NTs, duration of the entire sequence is roughly split between Ns and Ts. In addition, languages where NCs are clusters often exhibit both anticipatory and perseveratory nasal coarticulation (see Jeong 2012 for an overview), as do languages where NCs are segments. Finally, NC clusters do not appear to be articulatorily different from NC segments. Browman & Goldstein (1986) show that both English and Kichaga (Bantu) speakers produce labial [mb] with a single gesture; a difference in the phonological status of NC does not appear correspond to a difference in articulatory timing.

If the phonetic properties of NCs are not dependent on their phonological status, then the distribution of cues to N*NC and C*NC should not depend on it either[29]. If cue distribution does not depend on representational status, then the segment vs. cluster distinction is irrelevant for cue-based theories of phonotactics.

# 6 Conclusions

This study has shown that all identified cross-linguistic positional restrictions on NCs, as well as language-specific synchronic patterns, receive a unified explanation grounded in auditory and articulatory factors. More broadly, the study provides substantial evidence for the hypothesis that phonemic contrasts are first licensed in contexts of maximum perceptibility, and first neutralized in

[29]It is possible that precise cue weightings for the N*NC and C*NC contrasts could depend on the absolute timing of NC's component parts, which has been argued by Riehl (2008) and Cohn & Riehl (2012) to be dependent on the segment vs. cluster duration (though see Maddieson & Ladefoged (1993) for an opposing view).

contexts where relevant cues to the contrasts are absent (Steriade 1997). No single alternative is sufficient to account for the diversity of patterns presented here.

## References


2007. The UCLA Phonetics Lab Archive. Los Angeles, CA: UCLA Department of Linguistics.

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

Barnes, Jonathan Allen. 2002. *Positional Neutralization: A Phonologization Approach to Typological Patterns*: UC Berkeley dissertation.

Beckman, Jill N. 1998. *Positional Faithfulness*: UMass Amherst dissertation.

Beddor, Patrice Speeter & Chutamanee Onsuwan. 2003. Perception of prenasalized stops. In M.J. Solé, D. Recasens & J. Romero (eds.), *Proceedings of the 15th International Congress of Phonetic Sciences*, 407–410. Universitat Autònoma de Barcelona.

Blake, Barry J. 1979. *A Kalkatungu Grammar*. Department of Linguistics, Research School of Pacific Studies, Australian National University.

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

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

Browman, Catherine P. & Louis Goldstein. 1986. Towards an Articulatory Phonology. *Phonology Yearbook* 3. 219–252.

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

Chiţoran, Ioana. 2002. *The phonology of Romanian: a constraint-based approach*. Walter de Gruyter.

Childs, G. Tucker. 2011. *A Grammar of mani*. Mouton de Gruyter.

Chiosáin, Máire Ní & Jaye Padgett. 2010. Contrast, comparison sets, and the perceptual space. In Stephen Parker (ed.), *Phonological Argumentation*, Equinox.

Coady, James & Richard McGinn. 1982. On the so-called implosives of Rejang. In Ranier Carle et al. (ed.), *Gava': Studies in Austronesian Languages and Cultures Dedicated to Klaus Kähler*, 437–439. Reimer.

Coetzee, Andries & Rigardt Pretorius. 2010. Phonetically grounded phonology and sound change: The case of Tswana labial plosives. *Journal of Phonetics* 38. 404–421.

Cohn, Abigail C. 1990. *Phonetic and phonological rules of nasalization*: UCLA dissertation.

Cohn, Abigail C. & Anastasia K. Riehl. 2012. The internal structure of nasal-stop sequences: Evidence from Austronesian. In Becky Butler & Margaret E. L. Renwick (eds.), *Cornell Working Papers in Phonetics and Phonology*, vol. 3, .

Côté, Marie-Hélène. 2000. *Consonant cluster phonotactics: A perception-based approach*: MIT dissertation.

Côté, Marie-Hélène. 2004. Syntagmatic distinctness in consonant deletion. *Phonology* 21. 1–41.

Court, Christopher. 1970. Nasal harmony and some Indonesian sound laws. In S. A. Wurm & D. C. Laycock (eds.), *Pacific linguistics*, vol. C13, Australian National University.

Crowley, Terry. 1990. *An erromangan (Sye) grammar*. University of Hawai'i Press.

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

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

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

Davies, H. John. 1980. *Kobon phonology*. Department of Linguistics, Research School of Pacific Studies, Australian National University.

Dixon, Robert M. W. 1991. Mbabaram. In Robert M. W. Dixon & Barry Blake (eds.), *The handbook of Australian languages*, vol. 4, 349–402. Oxford University Press.

Donohue, Mark. 1999. *A grammar of Tukang Besi*. Mouton de Gruyter.

Donohue, Mark. 2002. Tobati. In John Lynch, Malcom Ross & Terry Crowley (eds.), *The Oceanic Languages*, 186–203. Curzon Press.

Downing, Laura J. 2005. On the ambiguous segmental status of nasals in homorganic NC sequences. In *The internal organizaiton of phonological segments*, 183–216. Mouton de Gruyter.

Durie, Mark. 1985. *A grammar of Acehnese on the basis of a dialect of North Aceh*. Foris Publications.

Endresen, Rolf Thiel. 1991. Diachronic aspects of the phonology of Nizaa. *Journal of African languages and linguistics* 12. 171–194.

Feinstein, Mark. 1979. Prenasalization and syllable structure. *Linguistic Inquiry* 10. 245–278.

Ferguson, Charles A. 1963. Assumptions about nasals: A sample study in phonological universals. In *Universals of language*, 53–60. MIT Press.

Flemming, Edward. 2002. *Auditory representations in phonology*. Routledge.

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

Goldsmith, John. 1990. *Autosegmental and Metrical Phonology*. Blackwell.

Guarisma, Gladys. 1978. *études vouté: langue bantoïde du Cameroun: phonologie et alphabet pratique, synthématique, lexique vouté-français*. SELAF.

Hagège, Claude. 1970. *La langue mbum de Nganha (Cameroun): phonologie, grammaire*. SELAF.

Halpert, Claire. 2012. Overlap-driven consequences of nasal place assimilation. In Mooshammer, Pouplier, Hoole & Kühnert (eds.), *Consonant clusters and structural complexity*, Mouton de Gruyter.

Hayes, Bruce & Tanya Stivers. 2000. Postnasal voicing. Ms., UCLA.

Heath, Teresa. 2003. Makaa (a83). In Derek Nurse & Gérard Philippson (eds.), *The bantu languages*, 335–348. Routledge.

Hedinger, Robert. 2008. *A grammar of Akoose: a Northwest Bantu language*. SIL International.

Herbert, Robert K. 1976. Phonetic analysis in phonological descrption: prenasalized consonants and Meinhof's Rule. *Lingua* 43. 339–373.

Herbert, Robert K. 1986. *Language universals, markedness theory, and natural phonetic processes*. Mouton de Gruyter.

Hercus, Louise Anna. 1986. *Victorian Languages: a Late Survey*. Department of Linguistics, Research School of Pacific Studies, Australian National University.

Hualde, José Ignacio & Jon Ortiz de Urbina (eds.). 2003. *A Grammar of Basque*. Mouton de Gruyter.

Hubbard, Kathleen. 1995. 'prenasalized consonants' and syllable timing: evidence from Runyambo and Luganda. *Phonology* 12. 125–156.

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

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

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

Jeong, Sunwoo. 2012. Directional asymmetry in nasalization: a perceptual account. *Studies in Phonetics, Phonology and Morphology* 18. 437–469.

Ka, Omar. 1994. *Wolof phonology and morphology*. University Press of America.

Kaplan, Abby. 2008. Markedness and phonetic grounding in nasal-stop clusters. Ms., UCSC.

Katzir Cozier, Franz. 2008. *The role of perception in phonotactic constraints: evidence from Trinidad English*: MIT MA thesis.

Kim, Yuni. 2008. *Topics in the Phonology and Morphology of San Francisco del Mar Huave*: UC Berkeley dissertation.

Ladefoged, Peter & Ian Maddieson. 1996. *The Sounds of the World's Languages*. Blackwell.

Lombardi, Linda. 1995. Laryngeal features and syllable well-formedness. *Natural Language and LInguistic Theory* 13. 39–74.

Łubowicz, Anna. 2012. *The Phonology of Contrast*. Equinox.

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

Maddieson, Ian. 1989. Prenasalized stops and speech timing. *Journal of the International Phonetic Association* 19. 57–66.

Maddieson, Ian & Peter Ladefoged. 1993. Partially nasal consonants. In Marie Huffman & Rena Krakow (eds.), *Nasals, nasalization, and the velum*, 251–301. Academic Press.

Massaro, D. W. & M. M. Cohen. 1983. Consonant/vowel ratio: An improbable cue in speech. *Perception and Psychophysics* 33. 501.

Mbodj, Chérif. 1983. *Recherches sur la phonologie et la morphologie de la langue Saafi: le parler de Boukhou*: Université de Nice dissertation.

McGregor, William. 1990. *A functional grammar of Gooniyandi*. John Benjamins.

Meinhof, Carl. 1932. *Introduction to the Phonology of the Bantu Languages*. Deitrich Reimer.

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

Michael, Lev, Tammy Stark & Will Chang. 2012. South American Phonological Inventory Database v1.1.2. Survey of California and Other Indian Language Digital Resource. Berkeley: University of California.

Monino, Yves & Paulette Roulon. 1972. *Phonologie du gbáyá kàrá 'bòdòè de Ndongue Bongowen, region de Bouar, République centrafricaine*. SELAF.

Mous, Maarten. 1993. *A gramar of Iraqw*. Buske Verlag.

Noyer, Rolf. 2013. A generative phonology of San Mateo Huave. *International Journal of American Linguistics* 79. 1–60.

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

Pater, Joe. 2001. Austronesian nasal substitution revisited: what's wrong with *nc (and what's not). In Linda Lombardi (ed.), *Segmental phonology in Optimality Theory: constraints and representations*, 159–182. Cambridge University Press.

Poser, William John. 1979. Nasal Contour Consonants and the Concept of Segment in Phonological Theory. B.A. thesis, Harvard University.

Press, Ian. 1987. *A Grammar of Modern Breton*. Mouton de Gruyter.

Riehl, Anastasia K. 2008. *The phonology and phonetics of nasal obstruent sequences*: Cornell University dissertation.

Robins, Robert H. 1957. Vowel nasality in Sundanese: a phonological and grammatical study. In *Studies in linguistic analysis (special volume of the Philological society)*, 87–103. Oxford.

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

Ross, Malcolm. 2002. Kaulong. In John Lynch, Malcolm Ross & Terry Crowley (eds.), *The Oceanic Languages*, 387–409. Curzon Press.

Rubach, Jerzy. 1990. Final devocing and Cyclic Syllabification in German. *Linguistic Inquiry* 21. 79–94.

Samarin, William. 1966. *The Gbeya Language: Grammar, Texts, and Vocabularies*. University of California Press.

Sharpe, Margaret C. 1972. *Alawa phonology and grammar*. Australian Institute of Aboriginal Studies.

Smith, Jennifer. 2002. *Phonological augmentation in prominent positions*: UMass Amherst dissertation.

Smith, Tony & Richard Gravina. 2010. *The phonology of two central Chadic languages*. SIL International.

Stanton, Juliet. 2012. Word-final consonant neutralization in Saafi. Ms., Indiana University.

Steriade, Donca. 1993. Closure, release, and nasal contours. In Marie Huffman & Rena Krakow (eds.), *Nasals, nasalization, and the velum*, 401–470. Academic Press.

Steriade, Donca. 1994. Positional Neutralization and the Expression of Contrast. Ms., UCLA.

Steriade, Donca. 1997. Phonetics in phonology: the case of laryngeal neutralization. Ms., UCLA.

Steriade, Donca & Jie Zhang. 2001. Context-Dependent Similarity: Phonology & Phonetics of Romanian Semi Rimes. Paper presented at CLS 37.

Tersis, Nicole. 1972. *Le zarma, Republique du Niger; etude du parler djerma de Dosso*. SELAF.

Thieberger, Nick. 2006. *A grammar of South Efate: an Oceanic language of Vanuatu*. University of Hawai'i Press.

Vandame, Charles. 1963. *Le Ngambay-Moundou: phonologie, grammaire et textes*. IFAN.

Westbury, John R. & Patricia Keating. 1986. On the naturalness of stop consonant voicing. *Journal of Linguistics* 22. 145–166.

Whalen, Douglas H. & Patrice S. Beddor. 1989. Connections between nasality and vowel duration and height: Elucidation of the Eastern Algonquian intrusive nasal. *Language* 65. 457–486.

Wright, Richard. 2004. A review of perceptual cues and cue robustness. In Bruce Hayes, Robert Kirchner & Donca Steriade (eds.), *Phonetically-based phonology*, 34–57. Cambridge University Press.

Zhang, Jie. 2002. *The effects of duration and sonority on contour tone distribution*. Routledge.