

**Constraints on the Distribution of Nasal-Stop Sequences:  
An Argument for Contrast**

by

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B.A., Indiana University (2012)

Submitted to the Department of Linguistics and Philosophy  
in partial fulfillment of the requirements for the degree of

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**Abstract**

It has been argued that certain typological generalizations regarding the distribution of nasal-stop sequences can be explained by explicitly referencing contrast (e.g. Herbert 1977, 1986; Jones 2000). This thesis explores the hypothesis that *all* generalizations regarding the distribution of nasal-stop sequences can be explained by explicitly referencing contrast, and presents the results of multiple cross-linguistic studies designed to test that hypothesis. I show first that taking into consideration cues to the contrasts between nasal-stop sequences and their component parts (nasals and stops) allows us to accurately predict generalizations regarding the distribution of phonemic nasal-stop sequences (i.e. those that are phonemically contrastive with other segment types). Following this I show that taking into consideration cues to the contrast between oral and nasal vowels allows us to accurately predict generalizations regarding the distribution of allophonic nasal-stop sequences (i.e. those not phonemically contrastive with other segment types), as well as generalizations regarding the distribution of phonemic nasal-stop sequences in the context of phonemically nasal and allophonically nasalized vowels. Broadly, the results presented here contribute to a larger body of evidence that constraints on contrast are a necessary component of the synchronic phonological grammar (following e.g. Lindblom 1986; Flemming 2002, 2008b; Padgett 2009).

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# Chapter 1

## Introduction

One of the questions that research in phonological theory seeks to answer regards the nature of the elements that make up the phonological grammar. Framed in Optimality Theoretic terms (Prince & Smolensky 2004), the question takes the following form: what kinds of constraints reside in CON?

On some points, there is little controversy. Most current practitioners of constraint-based theories agree that *markedness constraints*, or constraints that penalize certain marked output configurations, are a crucial component of the phonological grammar. And most current practitioners agree that *input-output faithfulness constraints*, which penalize changes between the input (or, underlying representation) and the output (or, surface representation) are also a necessary component of the phonological grammar. On other points, however, there is significant controversy. This study focuses on one: do *constraints on contrast distinctiveness* – constraints that evaluate acoustic differences among forms, and penalize contrasts that are insufficiently distinct (e.g. Lindblom 1986; Flemming 2002, 2008b; Padgett 2009) – belong in the phonological grammar?

Over the past twenty years or so, there has been an accumulation of results in the literature suggesting that the answer to this question is yes. It has been shown, for example, that if constraints on contrast are part of the phonological grammar, we can derive accurate predictions regarding the structure of phonemic inventories: the fact that central vowels are preferred in vowel systems that lack backness (or F2) contrasts but dispreferred elsewhere, for example, is easily accounted for by theories that acknowledge constraints on contrast (Flemming 2004; see also Lindblom 1986, Flemming 2002). It has also been shown that by appealing to constraints on contrast, we can make accurate predictions regarding cross-linguistic phonotactic generalizations: it is possible to predict the distribution of certain segment types by taking into account the perceptibility of contrasts they enter into, in different contexts (see e.g. Flemming 2002, Steriade 1997, Gallagher 2010). And more generally, a grammar that includes constraints on contrast lends the analyst a certain amount of explanatory power: appealing to the notion of contrast distinctiveness can help us understand why certain cross-linguistic markedness laws hold (see esp. Hayes & Steriade 2004 on this point).

But even with these arguments taken into account, there are potentially reasons to be skeptical. One common source of skepticism comes from the fact that adopting constraints on contrast distinctiveness entails the loss of a clear division between phonetics and phonology (see e.g. Boersma 2009:2 and citations there). Constraints on contrast distinctiveness, which evaluate auditory differences among forms, are able to refer to predictable phonetic properties. If constraints on contrast are a necessary part of the synchronic grammar, then the traditional view that phonetics and phonology are separate components of the grammar, and act independently (a view that goes back at least to Trubetzkoy 1939), cannot be correct. In addition, adopting constraints on contrast necessitates

the adoption of a more complicated model of the phonological grammar. Because constraints on contrast involve the comparison of output forms, adopting constraints on contrast requires us to assume a more complicated model of GEN – one that generates not just single forms, but rather sets of forms, each potentially infinite in cardinality (for discussion on this and other points, see e.g. Ní Chiosáin & Padgett 2010). And finally, there are often alternative explanations for apparent effects of contrast on synchronic phonological patterning (see e.g. Blevins 2004 and Boersma & Hamann 2008, who argue that apparent effects of contrast distinctiveness have diachronic explanations). Given these considerations, many authors choose to reject the hypothesis that constraints on contrast distinctiveness are part of the phonological grammar.

The work reported here contributes to this debate in that it provides a sustained argument from the distribution of nasal-stop sequences (NCs) that constraints on contrast are a *necessary component of the synchronic phonological grammar*. In what follows, I present the results of multiple cross-linguistic investigations into the distributional properties of nasal-stop sequences of all types: segments and clusters, underlying and derived. The results, which come from a set of original surveys totaling over 500 languages, show that there are a number of implicational generalizations that govern their distribution. I show that each of these generalizations can be predicted by a contrast-based approach to phonotactics, and that plausible alternative analyses (i.e. appealing to restrictions on the distribution of individual feature values, or to diachronic change conditioned by misperception) not only fail to predict the observed generalizations, but are also incapable of accounting for many of them without unjustified stipulation. The major conclusion of the study, then, is that constraints on the distribution of nasal-stop sequences are constraints on contrast: there is no single alternative that can account for the full range of generalizations presented here. By extension, then, any successful theory of the synchronic phonological grammar must include constraints on contrast.

Although the central claim of this study and the theoretical framework are not novel, this study is the first of its kind in offering an in-depth investigation of the role of constraints on contrast within a single empirical domain. It is also the first study to provide strong evidence that certain empirical predictions of contrast-based theories of phonotactics – such as a link between the typologies of neutralization and enhancement phenomena (see Flemming 2008a) – are borne out. Some of the results presented in this study also suggest limitations on the kinds of constraints on contrast that belong to CON, a novel finding that is discussed briefly in Chapter 5.

## 1.1 Outline of the study

The core of this study is made up of three chapters, each of which investigates a different aspect of the distribution of nasal-stop sequences. Chapter 2 (outlined in section 1.1.1) focuses on those nasal-stop sequences that contrast with plain nasal and oral stops (in English, for example, *land* contrasts with *LAN* and *lad*), and examines their distributional properties in different vocalic contexts. Chapter 3 (outlined in section 1.1.2) focuses on those nasal-stop sequences that arise as allophones of plain nasal stops (in many South American languages, for example, a plain nasal [m] that appears before an oral vowel, e.g. [a], is realized as [mb]), and examines their distributional properties with respect to different vocalic contexts. And Chapter 4 (outlined in section 1.1.3) focuses on the distribution of nasal-stop sequences with phonemically nasal and allophonically nasalized vowels: in many languages (including e.g. Páez, Rojas Curieux 1998, Jung 2008), a nasal-stop sequence cannot be followed by a nasal vowel (so ✓*pa*, ✓*pã*, and ✓*nda*, but \**ndã*). Throughout these three chapters, I show that all stated predictions of a contrast-based analysis regarding the distribution of

nasal-stop sequence are borne out. The final chapter summarizes the observed set of generalizations, and outlines several areas where further work would be productive.

These chapters present results from separate case studies, but they are intrinsically connected: a small collection of phonetic facts is responsible for deriving the entire set of generalizations. For example, it has been documented by a variety of authors, for a number of languages, that vowels display a greater extent of coarticulatory nasalization before non-prevocalic (or, roughly, coda) nasals than before prevocalic (or, roughly, onset) nasals; in other words, the first vowel in *amba* is expected to be marked by nasal formants for a larger portion of its duration than is the first vowel in *ama*, all else equal (see e.g. Schourup 1973, Jeong 2012). I show that this asymmetry plays a crucial role in predicting generalizations regarding the distribution of allophonic nasal-stop sequences (Chapter 3), as well as generalizations regarding the distribution of nasal-stop sequences with respect to nasal (or nasalized) vowels (Chapter 4). As is discussed at more length in Chapter 5, the fact that a set of seemingly disparate generalizations can be predicted from a small set of phonetic facts provides crucial support for the approach.

### 1.1.1 Chapter 2: constraints on the distribution of phonemic nasal-stop sequences

In a large number of languages, nasal-stop sequences contrast with plain nasal and plain oral stops. In many of these languages, however, the distribution of nasal-stop sequences is restricted: nasal-stop sequences occur in only a subset of the contexts in which oral and nasal stops occur. For example, in standard American English, voiced alveolar nasal-stop sequences are allowed word-finally (e.g. *land*), but voiced bilabial and velar nasal-stop sequences are not (so *lamb* is [læm], not \*[læmb]; *hang* is [hæŋ], not \*[hæŋg]). And while all voiced nasal-stop sequences are allowed intervocally (e.g. *ember*, *lander*, *younger*), none are allowed word-initially (\**mba*, \**nda*, \**nga*).

In Chapter 2, I show that cross-linguistic generalizations regarding the distribution of phonemic nasal-stop sequences can be predicted by taking into account cues to the contrasts between nasal-stop sequences and their component parts: plain nasal and plain oral stops. The cues to these contrasts come in two kinds: *internal* cues, or cues to the contrasts that lie within the contrasting segments themselves; and *external* (or *transitional*) cues, which lie in the surrounding environments (see e.g. Steriade 1997:9–10 on this distinction). For example: an internal cue to the contrast between nasals and nasal-stop sequences is the presence of the nasal-stop sequence's oral closure and release burst, and the nasal's lack of this acoustic feature. An external cue to the contrast between nasals and nasal-stop sequences is the nasal vs. oral quality of a following vowel: all else being equal, nasals are commonly followed by nasalized vowels, while nasal-stop sequences are followed by oral vowels. When both of these cues are present, the contrast is maximally distinct; if one or both cues are missing, the contrast is less distinct. Regarding the contrast between oral stops and nasal-stop sequences, we can draw a similar division: the *internal* cue to the contrast is the nasal-stop sequence's period of consonantal nasality (and the oral stop's lack of that nasality); the *external* cue is the nasal vs. oral quality of a preceding vowel, where the nasal-stop sequence is generally preceded by a period of vocalic nasality and the plain stop by a period of acoustic orality (see Beddor & Onsuwan 2003 for experimental verification of these cues, and Chapter 2 for more discussion of all of these points).

By building on results of perceptual experiments (Beddor & Onsuwan 2003), and adopting the hypothesis of Licensing by Cue (Steriade 1997, (1)), I show that we can make a strong set of predictions regarding restrictions on the distribution of nasal-stop sequences.

(1) 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  $C_1$ .

Regarding the licensing of a contrast between nasals and nasal-stop sequences (or the N–NC contrast), (1) allows us to predict that if a language licenses a word-final N–NC contrast, it must also license a prevocalic N–NC contrast. Recall from above that an *external* cue to the N–NC contrast is the nasal vs. oral quality of the following vowel; in word-final position, this cue is by definition unavailable. Thus the presence of a word-final N–NC contrast (where there are fewer cues) should imply its presence in prevocalic position (where there are more). And regarding the licensing of a contrast between oral stops and nasal-stop sequences (or the C–NC contrast), (1) allows us to predict that if a language licenses a word-initial C–NC contrast, it must also license a postvocalic C–NC contrast. Recall from above that an *external* cue to the C–NC contrast is the nasal vs. oral quality of the preceding vowel; in word-initial position, this cue is by definition unavailable. Thus the presence of a word-initial C–NC contrast (where there are fewer cues) should imply its presence in postvocalic position (where there are more).

I present results of a survey of 75 languages allowing nasal-stop sequences specifically designed to test the predictions outlined above. The results of the survey show that all predictions of the contrast-based approach are borne out. Cross-linguistically, nasal-stop sequences are optimally licensed in contexts where they are most distinct from their component parts, plain oral and nasal consonants. An additional prediction of the contrast-based approach is that these generalizations should hold regardless of whether the nasal-stop sequence is treated by the language’s phonology as a segment (or *prenasalized stop*, as in Sinhalese (Feinstein 1979) and other languages) or as a cluster (as in English and other languages); I show that this prediction, too, is borne out.

### 1.1.2 Chapter 3: constraints on the distribution of allophonic nasal-stop sequences

Chapter 3 broadens the claim that constraints on the distribution of nasal-stop sequences are constraints on contrast by focusing on a different kind of nasal-stop sequence: those that arise as a result of *environmental shielding*, a class of processes common to South American languages in which the realization of an underlying nasal consonant depends on the identity of the neighboring vowels. In many languages (e.g. Kaapor, Tupí, Garcia Lopes 2009), for example, /m/ is realized as [mb] when preceding an oral vowel (/ma/ → [mba]), but as [m] when preceding a nasal vowel (/mã/ → [mã]).

Herbert (1986:199) claims that environmental shielding occurs to protect a contrast in vocalic nasality (and this claim has since been echoed by a number of other scholars, including Steriade 1993a:448, Ladefoged & Maddieson 1996:103–106, Flemming 2004:256–258, Wetzels 2008). If the /m/ in /ma/ were realized as [m], it would likely induce some amount of nasal coarticulation on the following /a/ (so /ma/ → [m<sup>ã</sup>a] or [mã], where the superscripted [ã] stands for a period of transitional nasalization). Since a major perceptual cue to the contrast between oral and nasal vowels is a difference in the duration of acoustic nasality (see Whalen & Beddor 1989), nasalization of an oral vowel in a given context presumably reduces the perceptibility of the contrast between it and a nasal vowel in that same context. Shielding, or raising of the velum prior to the onset of the oral vowel, blocks coarticulatory nasalization from occurring. The result is that, when shielding occurs, the contrast between oral and nasal vowels is rendered maximally distinct.

I formalize an analysis of environmental shielding that makes crucial reference to the distance in the perceptual space between oral and nasal vowels, and show that a number of its typological predictions are borne out. For example, a contrast-based analysis of shielding predicts that shielding



phenomena should only be attested in languages that license a contrast in vocalic nasality: if there is no contrast in vocalic nasality to preserve, then there is no need to shield. Results from a survey of 324 languages in SAPHon (Michael et al. 2012) verify this prediction. In addition, I show that the contrast-based analysis makes correct predictions regarding asymmetries in the typology of shielding, as well as asymmetries in the broader typology of vowel nasalization contrasts. The final part of the chapter strengthens the argument for the contrast-based approach by showing that plausible alternative analyses (i.e. channel bias, spreading of certain featural values) fail to account for the full range of typological generalizations presented in this chapter.

### 1.1.3 Chapter 4: interactions between nasal-stop sequences and vocalic nasality

If constraints on contrast are part of the phonological grammar, as argued in Chapters 2 and 3, then we might expect to find evidence that they conflict with each other. In Chapter 4, I identify two phenomena that are best analyzed as conflicts among constraints on contrast. Both cases concern interactions between the distribution of nasal-stop sequences and vocalic nasality.

In the first half of the chapter, I identify a conflict between the constraints regulating distinctiveness of the contrasts between nasals and nasal-stop sequences on one hand, and plain oral stops and nasal-stop sequences on the other. I argue that the conflict between these constraints is what drives so-called nasal cluster dissimilation phenomena, such as Meinhof's Law in Bantu (e.g. Meinhof 1932, Meeussen 1963), where multiple nasal-stop sequences within a word are dispreferred (see Blust 2012 for a recent review). In contexts where two nasal-stop sequences are separated by a vowel (or NC<sub>1</sub>VNC<sub>2</sub> sequences), predictable anticipatory nasalization stemming from NC<sub>2</sub>, necessary for NC<sub>2</sub> to remain sufficiently distinct from a plain oral consonant, reduces cues to the contrast between NC<sub>1</sub> and a plain nasal consonant. As noted above, Beddor & Onsuwan (2003) have shown that external cues are important to the perception of the contrast between nasals and nasal-stop sequences: for the contrast to be maximally distinct, a nasal must be followed by a period of nasality and nasal-stop sequences must be followed by a period of orality. Thus, in an NC<sub>1</sub>VNC<sub>2</sub> sequence, the presence of an allophonically nasalized vowel following NC<sub>1</sub> may eliminate or reduce cues that the contrast between NC<sub>1</sub> and a plain nasal consonant relies on: a nasal-stop sequence followed by a nasal vowel is not maximally distinct from a plain nasal consonant. I develop a contrast-based account of nasal cluster effects, and show through a typological survey of 67 languages that its predictions are borne out. Furthermore, I argue that the contrast-based analysis of nasal cluster effects should be preferred to one in which nasal cluster effects are treated as a type of dissimilatory process (cf. Meinhof 1932, Blust 2012), as the dissimilation-based alternative is incapable of deriving many of the generalizations that the contrast-based analysis predicts.

Following this, I show that the observed cross-linguistic dispreference for NC<sub>1</sub>VNC<sub>2</sub> is just one symptom of a larger dispreference for NC $\tilde{V}$ ; that is, nasal-stop sequences followed by nasal vowels. I present results from a survey of 23 languages that allow both nasal-stop sequences and phonemically nasal vowels, and show that a number of these systems exhibit a dispreference for NC $\tilde{V}$ , either gradiently or categorically. The explanation for the observed dispreference for NC $\tilde{V}$  appeals, again, to a conflict between constraints on contrast: as noted above, a nasal-stop sequence must be followed by a period of orality to remain sufficiently distinct from a plain nasal consonant. In NC $\tilde{V}$  sequences, however, realization of this oral period in the nasal vowel would render the nasal vowel less nasal, and therefore less distinct from an oral vowel. It is thus impossible, in an NC $\tilde{V}$  sequence, for NC to be maximally distinct from N and for the nasal vowel to be maximally distinct from an oral vowel. I develop a contrast-based account of NC $\tilde{V}$  licensing, and show that it correctly predicts asymmetries among the types of attested NC $\tilde{V}$  sequences.

The phenomena discussed in Chapter 4 show that constraints on contrast can conflict, and that such conflicts have consequences – both typologically, and within the phonologies of individual languages. In this way, the phenomena discussed in this chapter provide further support for the claim that constraints on the distribution of nasal-stop sequences are constraints on contrast.

## 1.2 Theoretical background

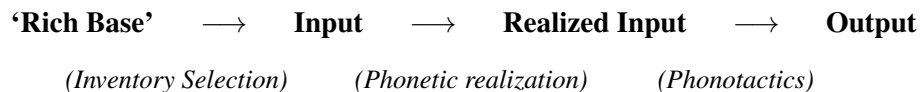
The analyses presented in this study are framed in Dispersion Theory (Flemming 2002), and assume the organization of the phonological grammar outlined by Flemming (2008b).<sup>1</sup> It is important to note that this decision does not represent a belief on my part that Flemming’s (2008b) model is the *only* model that could ever be capable of analyzing the distributional properties of nasal-stop sequences. The main argument of this study is simply that any successful analysis of their distribution *must explicitly reference contrast and phonetic detail* – I have selected Flemming’s model to illustrate one possible analysis of the typology because it is, as far as I am aware, the only existing model that satisfies these desiderata in its current form. Of course, the success of Flemming’s model in this domain does not rule out the possibility of future, more desirable alternatives.

This section introduces those aspects of the model that will be crucial to understanding the analyses presented in chapters 2 through 4. More detailed aspects of the model will be introduced over the next few chapters, when they are more relevant to the discussion at hand.

### 1.2.1 The model

There is growing amount of evidence that, in order to be able to account for certain phonological generalizations, the phonotactic grammar must be able to access predictable phonetic information (see e.g. Jun 1995, 2002; Zhang 2002; Kawahara 2006; Gallagher 2007; the present study; see Flemming 2008b for a summary). As noted at the beginning of the chapter, this desideratum is at odds with the more widely held view that phonetic implementation must follow, and therefore cannot influence, the phonological computation. In order to let a language’s phonology “see” predictable phonetic information, Flemming (2008b) proposes to divide the phonological grammar into several sequenced components, each of which employs a slightly different set of constraints (drawn from the same total ranking), and performs a different function. The proposed organization of the grammar, from Flemming 2008b:10, is schematized in (1).

(2) Architecture of the grammar in Flemming (2008b)



In (1), ‘Inventory Selection’, ‘Phonetic realization’, and ‘Phonotactics’ refer to three sequenced components of the grammar. In the inventory selection component, a language’s phonemic inventory is selected from a rich base. Once the phonemic inventory has been derived, sequences of sounds from the inventory combine to form the input to the next component of the phonological grammar: phonetic realization. The result of the phonetic realization component of the grammar is the Realized Input, which is the “expected phonetic realization of the input segment sequence, without substantial changes to the input, such as neutralizing deletions, assimilations, etc” (Flemming

<sup>1</sup>For other frameworks explicitly referencing contrast or other developments on Flemming’s (2002) model, see e.g. Ní Chiosáin & Padgett 2010, Łubowicz 2012.

2008b:14). The Realized Input is then evaluated by the phonotactic component of the grammar; the outputs of the phonotactic component of the grammar are the language’s surface forms. The property of the model most important for the present work is the ability of phonotactic constraints to “see” phonetic information, as the level of representation they evaluate – the Realized Input – is phonetically detailed.

While Flemming (2008b) maintains the assumption that each language’s grammar is made up of a single ranking of constraints, he claims that different kinds of constraints are active in different components of the grammar. In the inventory selection component, distinctiveness constraints (explored in more detail below) and segment-internal markedness constraints interact to shape a phonemic inventory. In the phonetic realization component of the grammar, segment-internal markedness constraints, context-sensitive articulatory constraints, prosodic constraints, and cue realization constraints (a type of correspondence constraint that encourages realization of perceptual targets) interact to derive the expected phonetic realization of sounds or sequences of sounds from the inventory. And then finally, in the phonotactic component of the grammar, all of the constraint types already mentioned, plus others (including standard-issue correspondence constraints) work together to place restrictions on sequences of sounds. This division is summarized in (3).

(3) Constraint types active in the phonological grammar (adapted from Flemming 2008b:10)

Component	Distinctiveness constraints	Segment-internal markedness constraints	Context-sensitive articulatory constraints	Prosodic constraints	Cue realization constraints	Correspondence constraints
Inventory	✓	✓				
Phonetic realization		✓	✓	✓	✓	
Phonotactics	✓	✓	✓	✓		✓

The next subsections briefly illustrate how each component works, in order to provide a sense of how the three components of the model work together to form a single phonetic-phonological grammar. It is worth noting, however, that the analyses in this study focus almost exclusively on the phonotactic component of the grammar, and largely abstract away from the inventory selection and phonetic realization components. While this means that the analyses that follow are not entirely complete, such a simplification does not detract from the primary goal of this study: to argue that constraints on the distribution of nasal-stop sequences are constraints on contrast.

### 1.2.2 Components of the model

The example we will consider here is of a hypothetical system that licenses three kinds of oral or partially-oral stops: voiceless (i.e. *t*), voiced (i.e. *d*), and prenasalized voiced stops (i.e. *nd*; these contrasts established in the inventory selection component of the model). In this system, prenasalized voiced stops are prohibited from occurring in initial position (this restriction established in the phonotactic component of the model, with reference to the output of the phonetic realization component). The example presented here is simplified in a number of ways, but suffices to illustrate the interaction of the assumed components of the grammar. The discussion of the inventory selec-

tion component below largely follows Flemming 2004’s discussion of prenasalization as a form of voicing enhancement (on this point see also Chapter 5.2.2), and the analysis of restrictions on initial prenasalized stops is discussed in much more detail in Chapter 2.

### Inventory selection

It is possible to conceive of voiceless, voiced, and prenasalized stops as residing along a continuum for voicing intensity. Voiced stops are more voiced than are voiceless stops; prenasalized stops can in addition be seen as more voiced than voiced stops, as the associated velum lowering “allows air to be vented from the vocal tract, [mitigates] the pressure build-up, and thus [facilitates] the maintenance of high intensity of voicing” (Flemming 2004:258ff; see this reference for citations and further discussion). If we assume that [voice] can have numeric values, then the scale in (4) represents one possible way of expressing these differences (scale after Flemming 2004:260).<sup>2</sup>

- (4) Scale of voicing intensity
- |   |   |    |                |
|---|---|----|----------------|
| 0 | = | t  | (voiceless)    |
| 1 | = | d  | (voiced)       |
| 2 | = | nd | (prenasalized) |

For simplicity’s sake, we will assume that the kinds of oral stops that a language can exhibit are composed of only those stops in (4). Which of these stops are chosen for a given language’s inventory will depend on how that language prioritizes three conflicting demands: the need to *maximize the distinctiveness of contrasts*, the need to *maximize the number of contrasts*, and the need to *avoid articulatory effort* (Flemming 2002:4).

In Dispersion Theory, the demand to maximize the distinctiveness of contrasts is encoded as a set of MINDIST (or MINIMUM DISTANCE) constraints, which specify the minimum acoustic distance between two sounds that is necessary for them to be sufficiently distinct. We can define MINDIST constraints for [voice] by appealing to the scale in (4). The MINDIST constraint in (5), for example, requires stops to differ in [voice] by a value of at least 1; the MINDIST constraint in (6) requires stops to differ in [voice] by a value of at least 2.

- (5) MINDIST = VOICE:1: contrasting oral stops must differ by at least 1 in [voice].
- (6) MINDIST = VOICE:2: contrasting oral stops must differ by at least 2 in [voice].

All possible contrasts made up of the segments in (4) satisfy MINDIST = VOICE:1, but fewer of these contrasts satisfy MINDIST = VOICE:2. Violations of the MINDIST constraints in (7) are annotated with the contrasting pairs that violate them.

- (7) Evaluation of the MINDIST constraints in (5–6)

	MINDIST = VOICE:1	MINDIST = VOICE:2
a. t–d		*! <sub>t–d</sub>
☞ b. t–nd		
c. d–nd		*! <sub>d–nd</sub>
d. t–d–nd		*! <sub>t–d</sub> * <sub>d–nd</sub>

Notice that [t–nd] emerges as the optimal candidate, under either ranking of constraints. But this is not exactly the result we want: the system we are attempting to derive licenses a three-way contrast

<sup>2</sup>The scale in (4) is a simplification; there are categories of stops that have been excluded (e.g. implosive stops, aspirated voiceless stops). These exclusions do not affect the discussion that follows.

[[t–d–nd]], and there are additionally systems that license a two-way contrast between voiced and voiceless stops ([t–d], e.g. French). In order to derive these systems, it is necessary to introduce constraints that encode the other two demands listed above: *maximize the number of contrasts*, and *avoid articulatory effort*.

The demand to maximize the number of contrasts is formalized in Dispersion Theory as a positively evaluated constraint, MAXCONTRAST, which prefers candidate inventories that have more contrasting forms (see also Padgett 2009 on \*MERGE, a negatively evaluated alternative; the two constraints are equivalent for the present purposes).

- (8) MAXCONTRAST: for a candidate with  $x$  members, assign MAXCONTRAST a value of  $x$ . Higher values of  $x$  are better than lower values of  $x$ .

As shown in (9), the ranking of MAXCONTRAST with respect to MINDIST = VOICE:2 determines whether the candidate has two or three members; the possible outputs are now (9b), [t–nd] (where the distinctiveness of contrasts has been maximized), and (9d), [t–d–nd] (where the number of contrasts has been maximized).

- (9) Tradeoff between satisfying MAXCONTRAST and MINDIST = VOICE:2

	MAXCONTRAST	MINDIST = VOICE:2
a. t–d	2	* <sub>t–d</sub>
☞ b. t–nd	2	
c. d–nd	2	* <sub>d–nd</sub>
☞ d. t–d–nd	3	* <sub>t–d</sub> * <sub>d–nd</sub>

In order to derive systems that license a two-way [t–d] contrast, it is necessary to include a constraint that disprefers candidate sets that contain [nd]. This markedness constraint, formalized in (10), is presumably a constraint on articulatory effort: prenasalized stops are articulatorily more complex than plain voiced or voiceless stops, as they involve precise coordination between gestures of the velum and gestures of the tongue.

- (10) \*NC: assign one \* for each prenasalized stop present in the output.

As shown in (11), if \*NC is high-ranked, the only inventory that can be selected is [t–d].

- (11) High-ranked \*NC yields [t–d]

	*NC	MAXCONTRAST	MINDIST = VOICE:2
☞ a. t–d		2	* <sub>t–d</sub>
b. t–nd	*!	2	
c. d–nd	*!	2	* <sub>d–nd</sub>
d. t–d–nd	*!	3	* <sub>t–d</sub> * <sub>d–nd</sub>

If \*NC is lower-ranked, then either [t–nd] or [t–d–nd] will be selected as optimal, depending on the relative ranking of \*NC and MINDIST = VOICE:2. The factorial typology that results from these three constraints is summarized in (12). (Note that I exclude MINDIST = VOICE:1 from the factorial typology below; as it assigns no violations, it plays no role in selecting the optimal candidate.)

- (12) Factorial typology with \*NC, MAXCONTRAST, MINDIST = VOICE:2

- a. [t–d] \*NC ≫ MAXCONTRAST, MINDIST = VOICE:2
- b. [t–nd] MINDIST = VOICE:2 ≫ MAXCONTRAST, \*NC
- c. [t–d–nd] MAXCONTRAST ≫ MINDIST = VOICE:2, \*NC

There is no possible ranking of these three constraints that can derive an inventory containing a two-way contrast between [d] and [nd]. This is because [d–nd] fails to fully satisfy any of the demands listed above: it does not maximize the distinctiveness of contrasts (as [d–nd] is not as distinct as [t–nd]), it does not maximize the number of contrasts (as [d–nd] has fewer members than [t–d–nd]), and it does not minimize articulatory effort (as it contains [nd]). The fact that a segment inventory containing only voiced and prenasalized stops cannot be derived is a desirable result, as systems of this kind are (to the best of my knowledge) unattested.

### Phonetic realization

Once the phonemic inventory has been determined, the phonetic implementation component of the grammar determines how these phonemes (and combinations thereof) are phonetically realized. At this stage in the grammar, all inputs must be made up of segments that are part of the phonemic inventory; put differently, after inventory selection has finished, the model no longer assumes richness of the base (on richness of the base see e.g. Smolensky 1996).

I assume here that the segment inventory [t–d–nd] has been derived through the constraint interaction discussed above. Now, we will focus here on one aspect of the phonetic realization of these segments: namely, the differing effects that [d] and [nd] have on a preceding vowel. It has been claimed, for a number of languages, that nasal-stop sequences induce a certain amount of *coarticulatory nasalization* on the preceding vowel (for more details on and citations for contextual nasalization, see esp. Chapter 3.2.1). Let us suppose that, in the hypothetical system under consideration, [nd] nasalizes the entire vowel that precedes it. One way to encode this regularity is by assuming that there is some markedness constraint, active in the phonetic realization component of the grammar, that requires all vowels preceding a nasal-stop sequence to be completely nasal. I formalize this constraint as NC-NASALIZEV1, in (13).

- (13) NC-NASALIZEV1: assign one violation mark \* if a nasal-stop sequence is not preceded by a fully nasalized vowel.

As shown in (14), if NC-NASALIZEV1 dominates \*NASALVOWEL, a segment-internal markedness constraint that disprefers nasal vowels, [nd] in postvocalic position will nasalize the entire vowel to its left. And as shown in (15), [d] in postvocalic position will not nasalize the vowel to its left, as NC-NASALIZEV1 is inapplicable. Note that, at this stage of the grammar, forms are evaluated independently of one another – the assumption is that distinctiveness constraints are not active when phonetic implementation is derived (as assumed already in (3)).

- (14) [nd] nasalizes a preceding vowel

anda	NC-NASALIZEV1	*NASALVOWEL
a. anda	*!	
☞ b. ãnda		*

- (15) [d] does not nasalize a preceding vowel

ada	NC-NASALIZEV1	*NASALVOWEL
☞ a. ada		
b. ãda		*!

It is worth reiterating here that this demonstration is a massive simplification of what occurs in the phonetic realization component of the grammar; see Flemming 2008b:13–14 for more (albeit still simplified) discussion. What is important for our purposes is only (i) that this component

of the grammar is where predictable phonetic properties are derived, and (ii) that it precedes the phonotactic component – to which we now turn.

## Phonotactics

The phonotactic component of the grammar takes as its input the output of the phonetic realization component; this phonetically detailed representation is termed the *Realized Input* (Flemming 2008b:8). We will focus on the utility of MINDIST constraints, segment-internal markedness constraints, and correspondence constraints at this stage, as these are the constraints that will figure most prominently throughout the rest of the study.<sup>3</sup>

Let us assume that, in this system, the contrast between [d] and [nd] is dependent on the presence a difference in the oral vs. nasal quality of the preceding vowel (for more discussion on cues to this contrast, see Chapter 2). This distinctiveness requirement can be encoded loosely as MINDIST D–ND =  $\Delta V1$  (see Chapter 2 for a revised formulation); this constraint requires D to be preceded by an oral vowel and ND to be preceded by a nasal vowel for the contrast to be sufficiently distinct. (I do not evaluate the distinctiveness of the contrast between [t] and {[d],[nd]} here, but assume that the difference between [t] and the others is marked by other cues, i.e. a difference in VOT).

- (16) MINDIST D–ND =  $\Delta V1$ : assign one violation mark \* if D is not preceded by an oral vowel and ND is not preceded by a nasal vowel.

In initial position, MINDIST D–ND =  $\Delta V1$  cannot be satisfied, as there is no preceding vowel. Whether or not the language tolerates the insufficiently distinct [d–nd] contrast depends on the ranking of several other constraints. One of these, a faithfulness constraint, prevents modification of the contrast (we will formalize this constraint as IDENT; see Chapter 2 for a more precise definition). If IDENT dominates MINDIST D–ND =  $\Delta V1$ , the language tolerates imperfect contrast; if MINDIST D–ND =  $\Delta V1$  dominates IDENT, the language is forced to modify the contrast.

Let us assume that the preferred modification here is neutralization: the initial [d–nd] contrast is insufficiently distinct, and so it is collapsed (though see Chapters 2–3 on enhancement as another possible solution to the problem of insufficiently distinct contrasts). We will assume here that the contrast between [da] and [nda] is neutralized to [da]; this preference for [d] is derived by low-ranked \*NC, present in the inventory selection and phonotactic components of the grammar (17).

- (17) In initial position, [d–nd] is insufficiently distinct

da–nda	MINDIST D–ND = $\Delta V1$	IDENT	*NC
a. da–nda	*!		
b. nda		*	*!
c. da		*	

As shown in (18), MINDIST D–ND =  $\Delta V1$  is satisfied in postvocalic position, and the contrast is licensed. As established in the phonetic realization component of the grammar, [nd] will nasalize a preceding vowel; thus [d] and [nd] differ as a function of the quality of the preceding vowel, and the [d–nd] contrast is, in this context, sufficiently distinct.

<sup>3</sup>Does MAXCONTRAST play a role in the phonotactic component of the grammar? Flemming (2008b) does not discuss this point, but I have yet to find a situation where its use is needed. Thus to simplify the model as much as possible, I assume that MAXCONTRAST is not active in the phonotactic component of the grammar, and that any apparent drive for contrast preservation is regulated by faithfulness constraints. This assumption holds throughout the chapters that follow.

- (18) In intervocalic position, [d–nd] is sufficiently distinct

	ad–ãnd	MINDIST D–ND = $\Delta V1$	IDENT	*NC
a.	ad–ãnd			
b.	ad		*!	*
c.	and		*!	

Again, the present discussion simplifies to a great extent the workings of the phonotactic component of the grammar; the analyses in the chapters that follow provide more detail. The important point here is that the constraints active in the phonotactic component of the grammar – MINDIST constraints like MINDIST D–ND =  $\Delta V1$ , faithfulness constraints like IDENT, and segment-internal markedness constraints like \*NC – are evaluated against the Realized Input, a fully phonetically-specified level of representation.

### 1.3 Summary and roadmap

The following chapters spell out a number of generalizations regarding the distribution of nasal-stop sequences, and show how these generalizations can be derived in the model just outlined.

The reader may notice, over the course of the study, that there is little to no evidence internal to the distribution of nasal-stop sequences that the phonological grammar must be divided into three sequenced components. For evidence that this division is necessary, the reader is referred to Flemming (2008b). Part of the reason for adopting this model here is that the separation of the grammar into different components lets us focus more narrowly on the role of constraints on contrast distinctiveness in the analysis of phonotactic generalizations, which is the main object of this study. Whether or not the set of generalizations presented here can be similarly accounted for in a simplified model that integrates inventory selection, phonetic realization, and phonotactics (i.e. the single-level model assumed in Flemming 2002) is a question I leave for future work.



## Chapter 2

# Constraints on the Distribution of Phonemic Nasal-Stop Sequences

This chapter presents an investigation into the distributional properties of phonemic nasal-stop sequences, i.e. those that are phonemically contrastive with other segment or sequence types in a given language. In English, for example, *and* forms a minimal pair with *an*; in Ngambay (Nilo-Saharan), *báo* ‘père [father]’ forms a minimal pair with *mbáo* ‘pêcheur [fisher]’ (Vandame 1963:4). In what follows, I present evidence from two cross-linguistic surveys demonstrating that there are consistent cross-linguistic implicational generalizations that govern the distribution of phonemic nasal-stop sequences (NCs), both segments and clusters, and that these generalizations are predictable given consideration of the contexts in which nasal-stop sequences are distinct from, or, alternatively, confusable with their component parts (Ns and Cs). The major claim of this chapter is that *constraints on the distribution of phonemic nasal-stop sequences 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 the presence of the contrast in contexts where cues are maximally available. I provide an analysis of the typology framed in Dispersion Theory (Flemming 2002, Flemming 2008b), and show that all patterns receive a unified explanation grounded in auditory and articulatory factors.

The first part of this chapter examines the acoustic, perceptual, and distributional properties of NC segments, or *prenasalized stops* (the distributional properties of NC clusters are discussed in section 2.4). Prenasalized stops are a type of phonetically complex segment composed of two sequenced parts: a nasal portion acoustically similar to a pure nasal consonant, and an oral portion acoustically similar to a pure oral consonant. Prenasalized stops are typically found in the languages of Africa, Oceania, and South America (Herbert 1986). A sample stop inventory containing prenasalized stops – that of Ngambay (Nilo-Saharan, Vandame 1963) – is below (1).

- (1) Stop inventory of Lua (Boyeldieu 1985)

	<i>Bilabial</i>	<i>Alveolar</i>	<i>Palatal</i>	<i>Velar</i>
<i>Voiceless</i>	p	t	c	k
<i>Voiced</i>	b	d	ɟ	g
<i>Prenasalized</i>	mb	nd	ɲɟ	ŋg
<i>Implosive</i>	ɓ	ɗ		
<i>Nasal</i>	m	n		

A general question arises here regarding how we know that the NCs of Ngambay are segments, not clusters. The distinction between NC segments and NC clusters is usually made on distributional

grounds (though cf. Riehl 2008, Cohn & Riehl 2012): in languages where NCs are said to be segments, they can appear in positions where other clusters, or sonority-violating clusters, cannot. In Ngambay, for example, NC sequences can occur word-initially, but initial clusters are otherwise disallowed (so ✓[mba] and ✓[nda], but \*[tra], \*[kla]).

While the question of how to distinguish NC segments from NC clusters is an interesting one (for discussion see e.g. Ferguson 1963, Anderson 1976, Poser 1979, Herbert 1986, Downing 2005, Riehl 2008, Cohn & Riehl 2012; see also Chapter 2.4.3 of this thesis), it will ultimately be irrelevant here; our focus is on the fact that the distribution of segment NCs is often restricted to certain positions within the word. While some languages, like Naman (Austronesian, Crowley 2006b), allow NCs at all positions in the word where other stops may occur, in others this is not the case. In Ngambay (Vandame 1963), for example, segment NCs can appear in word-initial and intervocalic position – but they cannot occur in word-final position, despite the ability of other stops (e.g. [p], [m]) to occur in that position. And in Kobon, segment NCs can occur intervocalically and word-finally – but not word-initially, despite the ability of other stops to occur in that position. The goal of this chapter is to determine what constraints govern the distribution of segment NCs. In other words: why, in some languages, is the distribution of NCs restricted?

(2) Restrictions on the distribution of segment NCs

<i>Language</i>	<i>Initial</i>	<i>Intervocalic</i>	<i>Final</i>
Naman (Crowley 2006b)	✓	✓	✓
Ngambay (Vandame 1963)	*	✓	✓
Kobon (Davies 1980)	✓	✓	*

The decision to focus this chapter first on prenasalized stops (or NC segments) was made primarily because they are better-studied than are NC clusters: there is more information available regarding how they are articulated, how they are perceived, and how they pattern phonologically. In what follows, we will see that by taking into account the acoustic and perceptual properties of NC segments, and by adopting the hypothesis of Licensing by Cue (Steriade 1997), we can make a number of predictions regarding the distribution of contrasts between NCs and their component parts, nasal consonants (Ns) and oral stops (Cs). In sections 2.2 and 2.3, I present results of a survey investigating the distributional properties of NC segments and show that the empirical findings correlate precisely with the predictions. Section 2.4 looks beyond the distribution of NC segments, and shows that the predictions also hold for the distribution of NC clusters; section 2.5 argues that this parallel between NC segments and NC clusters is the expected result, given what we know about the phonetics properties of NC clusters. Finally, section 2.6 discusses alternative analyses and concludes. The appendix to this chapter (in section 2.7) contains a list of languages consulted, supplemented with additional information regarding their genetic affiliation and consonantal phonologies.

## 2.1 Background and predictions

In this section, I summarize the results of phonetic studies focusing on prenasalized stops (sections 2.1.1, 2.1.2), set forth predictions regarding their distribution (section 2.1.3), and describe the survey undertaken to test these predictions (section 2.1.4).

### 2.1.1 Acoustics of NC segments

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 voiced nasal-stop segments (ND segments) are more or less equivalent to the acoustic properties of their component parts, Ns and Ds. The onset nasal murmur of ND segments is spectrally and durationally similar to the nasal murmur of Ns; the oral release bursts of ND segments do not differ systematically in amplitude compared to the release bursts of plain Ds.

Burton et al. also show that ND segments 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, ND segments 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. ND segments 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 NC segments (Maddieson & Ladefoged 1993, Ladefoged & Maddieson 1996: 4.3, Riehl 2008, Cohn & Riehl 2012) have corroborated the general conclusion that they are made up of two acoustically distinct parts, essentially equivalent to an N followed by a C.

Voiceless prenasalized stops (NT segments)<sup>1</sup> can be distinguished from Ns and ND segments by facts about their internal timing. Maddieson & Ladefoged (1993) show that, in Sukuma (Bantu), the duration of an NT segment's nasal component is significantly shorter than the duration of an ND segment's; for both NT and ND segments, the duration of the nasal portion is longer than the duration of a plain N. In addition, NT segments have longer oral closures and longer releases than do ND segments (Maddieson & Ladefoged 1993 for Sukuma; Coetzee & Pretorius 2010 for Tswana). Cross-linguistically, it appears that N takes up the majority of time allotted to an ND segment, but that N and T are more or less equally divided in an NT segment (Maddieson & Ladefoged 1993, Ladefoged & Maddieson 1996: 4.3, also Riehl 2008, Cohn & Riehl 2012). Schematic illustrations follow in (3). Additionally, given these durational differences, and the fact that the release bursts of voiceless stops are generally louder than those of voiced stops (see e.g. Repp 1979 on English), the difference in burst amplitude between an N and an NT segment is presumably greater than is the difference between an N and an ND segment (though cf. Coetzee & Pretorius 2010 on Tswana).

(3) Internal timing of NC segments

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



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



NC segments can also differ from other consonants according to the length of a preceding vowel. In Sukuma (Maddieson & Ladefoged 1993), vowels preceding NT segments are significantly shorter than those preceding Ns or ND segments. In some languages, vowels preceding ND segments are

<sup>1</sup>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 calling an NC sequence a "prenasalized stop" is that the sequence be inseparable – in other words, in a language 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 2008's framework. Many other examples of inseparable NT clusters exist; for additional examples, see Meinhof (1932:158) on Kongo, and Halpert (2012) on Zulu.

longer than vowels preceding Ns; whether or not such a vowel length difference exists, however, is language-dependent. Languages in which Ns and ND segments differ as a function of V1 duration are Luganda and Sukuma (Maddieson & Ladefoged 1993), CiYao and Runyambo (Hubbard 1995); languages where N and ND segments are not differentiated in this way include Fijian (Maddieson 1989), CiTonga (Hubbard 1995), Tamambo and Erromangan (Riehl 2008:113-116).

NC segments, Cs, and Ns can also be differentiated by the quality of surrounding vowels. In languages where oral and nasal vowels do not contrast, NC segments are followed by oral vowels, and Ns are followed by nasal vowels. Evidence from a variety of languages suggests that carryover nasalization is common, and to simplify matters here, the analysis that follows will assume that it is universal (though cf. Chan & Ren 1987 on Miao). 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, Sango (Samarin 1967), and three Dayak languages (Court 1970). Schematic illustrations follow in (4).

(4) Vowel quality following N and NC segments (V2 quality)

- a. Vowels following NC: always oral (V)

NC	V
----	---

- b. Vowels following N: always nasal (Ñ)

N	Ñ
---	---

A similar difference in vowel quality is apparent, in some languages, for vowels preceding Cs vs. NC segments. Vowels preceding Cs are oral and vowels preceding NC segments are often nasalized. Instrumental evidence for nasalization preceding NC segments comes from Sukuma (Maddieson & Ladefoged 1993) and Tamambo (Riehl 2008:151-156); impressionistic descriptions of other languages report the same pattern (Vandame 1963:13 for Ngambay, Donohue 1999:29 for Tukang Besi, Herbert 1977:347, 350-351 and references there for others). There are, however, languages where vowels preceding NC segments do not appear to be nasalized: Luganda speakers do not nasalize vowels preceding NC segments (Maddieson & Ladefoged 1993, though cf. Herbert 1986).

(5) Vowel quality preceding Cs and NC segments (V1 quality)

- a. Vowels preceding NC: often nasal (Ñ)

Ñ	NC
---	----

- b. Vowels preceding C: always oral (V)

V	C
---	---

A table summarizing the discussion above, of the known acoustic differences between NC segments and other segment types, is below (Table 2.1). Each potential acoustic difference is annotated with a language that exhibits it; references are footnoted.<sup>2</sup> Note that these are only potential differences:

<sup>2</sup>Abbreviations used in the table: “Δ” = a perceptible difference in; dur. = duration. References for languages in the table: Beddor & Onsuwan 2003 (Ikalanga); Riehl 2008 (Manado Malay), p. 208; Burton et al. 1992 (Moru); Riehl 2008 (Pamona), p. 159; Maddieson & Ladefoged 1993 (Sukuma), p. 276 for N/ND and N/NT V1 dur., p. 280 for ND/NT V1 duration, p. 277 for N/ND and N/NT N dur., p. 279 for ND/NT N dur., p. 277 for T/NT V1 quality, p. 257 for ND/NT burst. Riehl (2008) argues that NTs are clusters in Pamona and Manado Malay; I cite these data here because I was unable to find spectrograms of N/NT and T/NT pairs for Sukuma, where NTs are claimed to be segments.

while all are attested more generally, not all will necessarily be present in a given context. In Table 2.1, cells that have been grayed out indicate distinctions that have not been shown to exist in any language that I am aware of. Gray cells containing a dash indicate a distinction that is not expected to exist.

Table 2.1: Summary of potential acoustic distinctions among NC segments, Ns, and C

	<i>N/ND</i>	<i>N/NT</i>	<i>D/ND</i>	<i>T/NT</i>	<i>ND/NT</i>
<i>V1 duration</i>	$\Delta$ V1 dur. Sukuma	$\Delta$ V1 dur. Sukuma			$\Delta$ V1 dur. Sukuma
<i>N duration</i>	$\Delta$ N dur. Sukuma	$\Delta$ N dur. Sukuma	$\Delta$ N dur. Moru	$\Delta$ N dur. Manado Malay	$\Delta$ N dur. Sukuma
<i>V1 quality</i>	—	—	$\Delta$ nasal Ikalanga	$\Delta$ nasal Sukuma	—
<i>V2 quality</i>	$\Delta$ nasal Ikalanga	$\Delta$ nasal Pamona	—	—	—
<i>Burst</i>	$\Delta$ burst Moru	$\Delta$ burst Manado Malay			$\Delta$ burst Sukuma

### 2.1.2 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 contrast between Ns and NC segments on one hand, and Cs and NC segments on the other. This section summarizes results of a two-part perceptual experiment (Beddor & Onsuwan 2003) probing the relative importance of two kinds of cues to these contrasts in Ikalanga (Bantu): *internal* cues, or auditory distinctions that reside within the contrasting segments; and *external cues*, or auditory distinctions that reside in the environment surrounding the contrasting segments. The discussion is supplemented with results from Kaplan’s (2008)’s perceptual study on N–NC cluster contrasts in English.

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

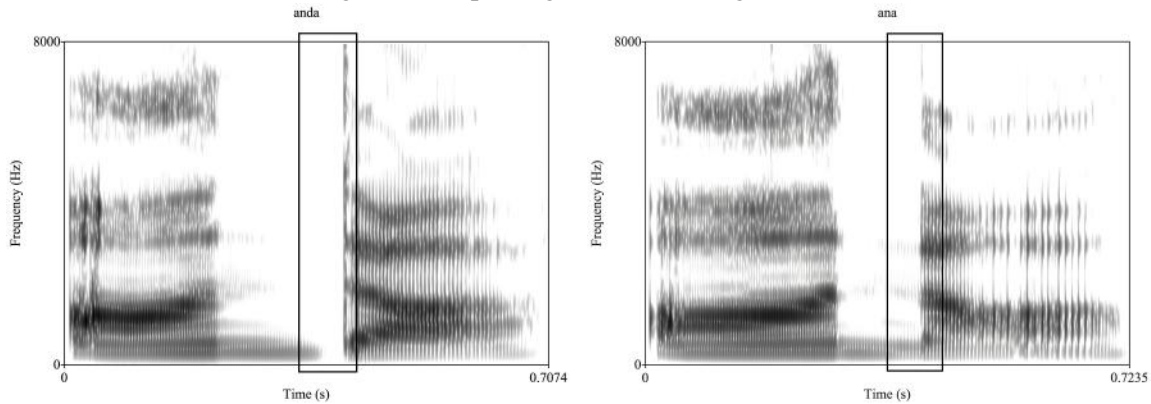
#### Perception of the N–NC contrast

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 segment. The relative duration of the oral occlusion varied independently 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 segments is the presence of the ND segment’s release burst vs. its absence for N. I refer to this cue as  $\Delta$  ***burst***, in (6) (where  $\Delta$  = “a perceptible difference in”). Throughout, perceptual cues appear in bold italics.

- (6) Internal cue to the contrast between Ns and ND segments  
 $\Delta \textit{burst}$

The acoustic distinction referenced by  $\Delta \textit{burst}$  can be seen in Figure 2-1 (this and other figures adapted from Stanton 2016b). Contexts where  $\Delta \textit{burst}$  is present include any environment in which NCs have a burst. For example,  $\Delta \textit{burst}$  is present in the contrast between [nã] and [nda], or [an] and (released) [and], as the NC has an oral release that the N does not. The cue is absent in any context where NCs do not have a release burst. For example, the contrast between [an] and [and̚] is not cued by  $\Delta \textit{burst}$ , because the word-final NC does not have an oral release.

Figure 2-1: Spectrograms illustrating  $\Delta \textit{burst}$



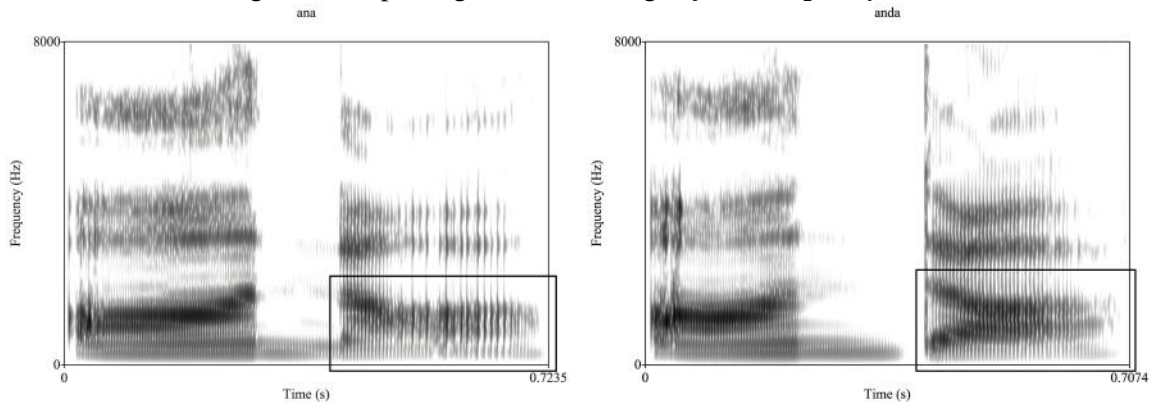
In addition to this internal cue, vowel quality following Ns and ND segments had a large effect on consonant identification. Ns were most identifiable when followed by nasal vowels, and most confusable with ND segments when followed by oral vowels. The opposite holds for ND segments: ND segments were most identifiable when followed by oral vowels, and most confusable with Ns when followed by nasal vowels. From this, we can generalize to say that an important external cue to the N–NC contrast is a difference in the nasal vs. oral formant structure of the immediately following segment, such that Ns are followed by a segment with nasal formants and NDs are followed by a segment with oral formants. I refer to this cue as  $\Delta \textit{formant quality (following segment)}$ , or  $\Delta \textit{formant quality (S}_2\text{)}$  for short (7), where “quality” refers to nasal vs. oral.

- (7) External cue to the contrast between Ns and ND segments  
 $\Delta \textit{formant quality (following segment)}$ , or  $\Delta \textit{formant quality (S}_2\text{)}$

The acoustic distinction referenced by  $\Delta \textit{formant quality (S}_2\text{)}$  can be seen in Figure 2-2. The presence of vocalic nasality is marked by a dampening and broadening of formant bandwidths, especially noticeable in the F1 region, and an additional weak nasal formant around 300 Hz (Wright et al. 1996). The presence of vowel nasalization is readily apparent from the boxed portion of /ana/ (Figure 2-2, left), especially when compared to the oral vowel in /anda/ (Figure 2-2, right).

$\Delta \textit{formant quality (S}_2\text{)}$  is present anywhere where the contrasting segments are followed by formants of the appropriate nasal vs. oral quality. For example,  $\Delta \textit{formant quality (S}_2\text{)}$  is present in the contrast between [nã] and [nda] (N preceding a phonemically nasal vowel, and ND preceding a phonemically oral vowel), because the N is followed by nasal formants and the NC is followed by oral formants. It is also present (although to a lesser extent) in the contrast between [nã̃a] and [ndã̃ã], because even though N is followed by a phonemically oral and NC by a phonemically nasal vowel, the consonants are followed by a period of nasal and oral formants, respectively. The cue is

Figure 2-2: Spectrograms illustrating  $\Delta$  *formant quality* ( $S_2$ )



absent word-finally (e.g. in the contrast between [ã̃n] and [ã̃nd]), or in any other context where the appropriate transitions are not present. In the comparison between [na] and [nda], for example, N is not followed by nasal formants, so  $\Delta$  *formant quality* ( $S_2$ ) is not present.

Speaker responses indicate that internal and external cues to the contrast between Ns and ND segments in Ikalanga are not equally important. Reliable identification of the contrast between Ns and ND segments is dependent on the presence of external cues: Ns must be followed by nasal formants, and NDs by oral formants, for accurate identification. On the basis of this finding, Beddor & Onsuwan (2003:3) conclude that external cues are both “necessary and sufficient” for perception of the contrast between Ns and ND segments. Impressionistic evidence suggests that the quality of a following segment is a vital cue to this 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 the N–ND contrast, then all else equal N–ND should be more distinct before a vowel, where  $\Delta$  *formant quality* ( $S_2$ ) is present, compared to the word-final context where  $\Delta$  *formant quality* ( $S_2$ ) is absent. Results from a perceptual study on the distinctions among Ns and released NC clusters in English (Kaplan 2008) confirm this prediction. (Kaplan’s is a study on clusters, but I do not expect that the results would differ according to sequence type; see section 2.4). While Ns and ND clusters were reliably identified intervocalically, all subjects frequently misidentified final ND clusters as Ns, and a subset of those subjects also frequently misidentified final Ns as ND clusters. Thus the N–ND contrast is distinct where external cues are present (prevocally) but confusable where external cues are absent (word-finally).

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 N–ND, perhaps because the N–NT contrast is marked by a number of non-release-associated cues (see section 2.1.1) that N–ND is not, as well as a larger difference in burst amplitude. Note however that speakers were less accurate at identifying final NTs than intervocalic NTs (Kaplan 2008:24), suggesting that  $\Delta$  *formant quality* ( $S_2$ ), although less necessary, is still an important cue.

### Perception of D–ND

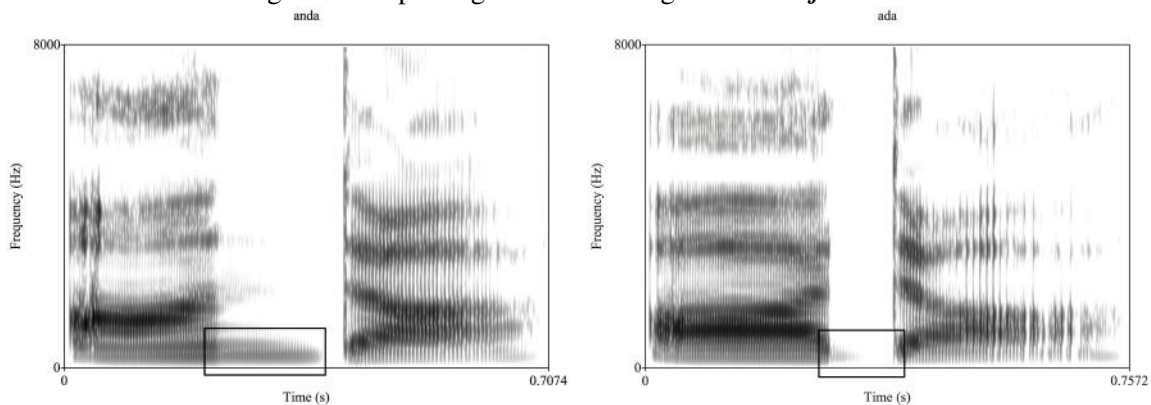
Beddor & Onsuwan’s (2003) second identification task reveals that both internal and external cues are important to the Ikalanga D–ND segment contrast. Stimuli were created by varying the duration of acoustic nasality in the preceding vowel with the duration of ND’s nasal consonant formants.

Speakers reliably identified the stimuli as Ds when the consonant was entirely oral, and increasingly as ND segments 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 (visible mainly as a weakening of the upper formants and an additional low frequency resonance below 500Hz; see e.g. Wright et al. 1996:11): ND segments have them, but Ds do not (8).

- (8) Internal cue to the contrast between D and ND segments  
 $\Delta$  *nasal consonant formants*, or  $\Delta$  *nasal C formants*

The acoustic distinction referenced by  $\Delta$  *nasal C formants* can be seen in Figure 2-3. As is evident from the comparison between /anda/ (Figure 2-3, left) and /ana/ (Figure 2-3, right), consonantal nasality is visibly marked by a low-frequency resonance.

Figure 2-3: Spectrograms illustrating  $\Delta$  *nasal C formants*



The longer the nasal portion of NC, the more robust a cue  $\Delta$  *nasal C formants* is to the C–NC contrast. For example, as Ns are long in voiced NC sequences (NDs),  $\Delta$  *nasal C formants* is a robust cue to the D–ND contrast. As Ns are shorter in voiceless NC sequences, however,  $\Delta$  *nasal C formants* is a less robust cue to the T–NT contrast.

Identification of Ds and ND segments is also affected by the quality of the preceding segment. Though the magnitude of this effect was fairly small, stimuli were more likely to be identified as Ds when preceded by oral vowels, and more likely to be identified as ND segments when preceded by nasal vowels. Generalizing from this, we can say that an external cue to the D–ND contrast is the presence of a difference in the oral vs. nasal formant structure of the preceding segment: Ds and ND segments are most distinct when Ds are preceded by a segment with oral formants, and NDs are preceded by a segment with nasal formants (9).

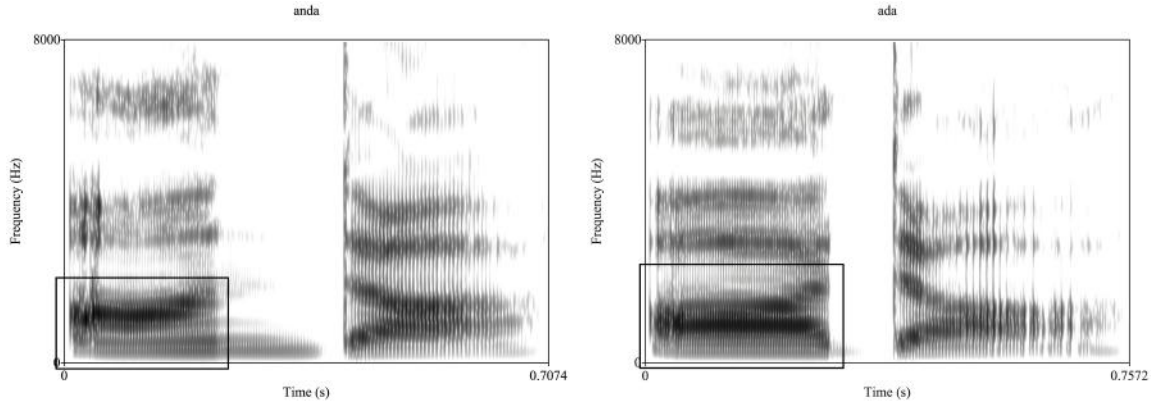
- (9) External cue to the contrast between Ds and ND segments  
 $\Delta$  *formant quality (preceding segment)*, or  $\Delta$  *formant quality ( $S_1$ )*

The acoustic distinction referenced by  $\Delta$  *formant quality ( $S_1$ )* can be seen in Figure 2-4. The presence of vowel nasalization (esp. dampening and widening of F1) is readily apparent from the circled portion of /ana/ (Figure 2-4, left), especially when compared to the circled portion of the oral vowel in /anda/ (Figure 2-4, right).

$\Delta$  *formant quality ( $S_1$ )* is present in contexts where the appropriate difference in formant quality is present.  $\Delta$  *formant quality ( $S_1$ )* is present in the [ada] vs. [ãnda], for example, as C is preceded by oral transitions and NC is preceded by nasal formants. It is also present in the contrast between



Figure 2-4: Spectrograms illustrating  $\Delta$  *formant quality* ( $S_1$ )



[ada] and [a<sup>̃</sup>nda]: even though the vowel preceding NC is oral, the consonant is still preceded by nasal formants. Contexts where  $\Delta$  *formant quality* ( $S_1$ ) are absent include word initial position (e.g. [da] vs. [nda]) and all other positions in which the appropriate difference in formant quality is not present. For example,  $\Delta$  *formant quality* ( $S_1$ ) is not present in [ãda] vs. [ãnda] because C is not preceded by oral formants.

Finally, recall that reliable identification of Ns and ND segments in Ikalanga is affected by the presence of internal cues ( $\Delta$  *burst*), but dependent on the presence of external cues ( $\Delta$  *formant quality* ( $S_2$ )). For the D–ND contrast, the presence of internal cues 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 segmental duration (as in other languages; see section 2.1.1). Ds and ND segments can be reliably identified when  $\Delta$  *formant quality* ( $S_1$ ) is 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 D–ND internal cues are less robust.

### 2.1.3 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 on 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 above are in (10) and (11); further predictions are discussed in Chapter 4.

- (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  $\Delta$  *formant quality* ( $S_2$ ) is present. No language should license an N–NC segment contrast where  $\Delta$  *formant quality* ( $S_2$ ) is absent (word-finally) but neutralize it where  $\Delta$  *formant quality* ( $S_2$ ) is present (prevocalically). We expect initial C–NC to imply postvocalic C–NC (11) because C–NC is better-cued in postvocalic position, where  $\Delta$  *formant quality* ( $S_1$ ) is present. No language should license an C–NC segment contrast where  $\Delta$  *formant quality* ( $S_1$ ) is absent (word-initially) but neutralize it where  $\Delta$  *formant quality* ( $S_1$ ) is present (postvocalically). In addition, as

the results from Beddor & Onsuwan’s study suggest that C–NC is less dependent on external cues than is 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 possible 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, Lombardi 1995). The prediction in (10) could potentially be captured under such an analysis: like other marked segment types, we might expect NC segments to be preferred in onset position but dispreferred 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 NC segments should be preferred over word-initial NC segments. A contrast-based analysis, however, does. The fact that (11) is the correct prediction (see section 2.3) favors a contrast-based analysis of the distribution of NCs, as the analysis predicts all and only the observed contextual asymmetries.

#### 2.1.4 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 segment contrasts. Languages with NC segments were identified through a large-scale investigation spanning journal articles, databases (e.g. SAPHon, Michael et al. 2012), and a collection of reference grammars from three libraries. I used purely phonotactic criteria to distinguish between NC segments and NC clusters: if an NC sequence can appear where other clusters (or sonority-violating clusters) cannot, I treated it as a single segment.<sup>3</sup> An additional prerequisite for inclusion in the survey was that the language allow obstruent stops in initial, intervocalic, and word-final position. As NC segments are best considered a kind of obstruent stop (see discussion in Maddieson 1984:67–68, Steriade 1993a), it is reasonable to expect that they will 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 in which the status of final obstruent stops was unclear. In Kalkatungu (Blake 1979), for example, unreleased [t] and the trill [r] are in free variation word-finally. It is unclear if the apparent word-final [t] is a true example of a word-final obstruent, or just an unreleased /r/. The sample is representative of a number 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. The results of this survey are discussed in sections 2.2 and 2.3: section 2.2 focuses on the distribution of the N–NC contrast, while section 2.3 focuses on the distribution of the C–NC contrast.

## 2.2 Final NC segments and the N–NC contrast

Results from the survey verify the prediction in (10): if a language licenses a contrast between Ns and NC segments word-finally, it also licenses this contrast prevocally. Section 2.2.1 presents the survey results, and establishes that the prediction is correct. Section 2.2.2 provides an analysis of the typology framed in Dispersion Theory (Flemming 2002, 2008b). Section 2.2.3 discusses an alternative analysis, appealing to possible language-specific differences in the phonetics of NCs.

<sup>3</sup>But see section 5 for evidence that the predictions in section 2.3 hold regardless of NC sequence type.

Sections 2.2.4 and 2.2.5 discuss the importance of  $\Delta$  *burst*, and provide some evidence that the link between perception and phonological contrast is synchronically active.

It is worth noting that the reason for focusing on the word-final context, to the exclusion of pre-consonantal context, is that there is not a lot of available data regarding the behavior of NCs in the preconsonantal context: very few of the languages surveyed allow obstruents stops in preconsonantal position. For the languages that do, the prediction is that if the language allows N–NC in preconsonantal position (where external cues to the contrast are compromised), the language should allow N–NC in prevocalic position (where external cues to the contrast are present). To the best of my knowledge, this prediction is correct (see e.g. Mbodj 1983 on Boukhou Saafi, where NCs are allowed prevocalically but not preconsonantly).

### 2.2.1 Survey results

Of the 50 surveyed languages, all license N–NC prevocalically, and 19 license N–NC prevocalically and word-finally. No language licenses N–NC word-finally only. Languages licensing N–NC both prevocalically and word-finally are ‘permissive’ (so-called because they license N–NC in all relevant contexts); languages licensing N–NC prevocalically only are ‘restrictive’ (so-called because they do not license N–NC in all relevant contexts). Examples of each type of system are below (12); see the appendix (section 2.6.1) for a full listing of the languages in each category.

(12) Survey results for N–NC contrast

Permissive ( $\checkmark\_V$ , $\checkmark V\_ \#$ )	Restrictive ( $\checkmark\_V$ , $*V\_ \#$ )	Other ( $*\_V$ , $\checkmark V\_ \#$ )
<i>19 languages, e.g.</i> Avava (Crowley 2006a) Naman (Crowley 2006b) Páez (Rojas Curieux 1998)	<i>31 languages, e.g.</i> Acehnese (Durie 1985) Alawa (Sharpe 1972) Lua (Boyeldieu 1985)	<i>0 languages</i>

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, we cannot say that a ban on final NCs is just part of a larger ban on final clusters, because the constraints on the distribution of NC segments do not necessarily parallel constraints on the distribution of clusters. Alawa (Sharpe 1972) permits final clusters but bans final NC segments; many languages, including Boukhou Saafi (Mbodj 1983) and Naman (Crowley 2006b), permit final NC segments but ban final clusters. We also cannot say that constraints on the distribution of NCs parallel more general constraints on the distribution of released stops (cf. Steriade 1993a), because the presence or absence of final NC segments 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 NC segments; Neverver (Barbour 2012) bans final released Cs but allows final NC segments; and Wolof bans final released Cs but allows final released NC segments. Finally, the presence or absence of final ND segments cannot be attributed to more general restrictions on final voiced obstruents. Wolof (Ka 1994), Boukhou Saafi (Mbodj 1983), and Basáa (Hyman 2001) allow final ND segments but not Ds. Jabêm (Bradshaw & Czobor 2005) allows final Ds but not ND segments.

Several of these points are discussed more fully in the context of the proposed analysis. While it might appear that restrictions on final NCs parallel restrictions on final clusters or final voiced obstruents, the wide variety of patterns cited above suggests that these links are not causal. Rather, restrictions on final NC segments look superficially similar to restrictions on final Ds and final clusters because the final N–NC contrast, like laryngeal and singleton-cluster contrasts (see Steriade 1997, Katzir Cozier 2008), is mostly dependent on release-associated cues.

### 2.2.2 N–NC: constraints and analysis

The analyses proposed here are in the framework of Dispersion Theory (Flemming 2002, 2008b), as outlined in the introduction. A contrast-based framework is particularly suited for the analysis of the N–NC and C–NC typologies because contextual neutralization is better analyzed as a suspension of contrast rather than a distributional restriction targeting certain classes of segments. Evidence for this comes from languages in which neutralization results in free variation (see Steriade 1994, Flemming 2002:40–41, Flemming 2004). A class of examples particularly relevant to the discussion at hand are languages in which voiced stops in initial position are in free variation with voiced prenasalized stops (as in Ho, Pucilowski 2013).<sup>4</sup> The absence of a contrast between Ds and NDs in initial position cannot be due to the ban of the appearance of one segment type or another, as both are capable of appearing in that position. This pattern and others cited by Flemming and Steriade 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 segment contrast: a difference in the nasal vs. oral formant quality of the following segment ( $\Delta$  *formant quality* ( $S_2$ )), and the presence vs. absence of an oral closure and release burst ( $\Delta$  *burst*). While there very well may be other important cues to the N–NC segment contrast (e.g. a difference in duration of the preceding vowel, or a difference in the duration of the nasal component; see section 2.1.1), this analysis focuses on only those cues that have been experimentally verified. I start with the hypothesis that the minimum acoustic difference necessary for reliable distinction of Ns and NC segments is the presence of one or the other of these cues (13). (In (13), I use only the variable  $n$  to refer to the necessary durations of nasal and oral formants. Determining which timepoint  $n$  stands for is not necessary to analyze the phenomena discussed in this chapter, but see Chapter 4 for some further discussion.)

- (13) MINDIST N–NC ( $\Delta$  BURST OR  $\Delta$  FQUALITY ( $S_2$ )): assign one violation for every N–NC pair in the output that does not differ in either (i) burst amplitude or (ii) the nasal vs. oral quality of the following segment, such that:
- N is followed by a segment that, from its beginning to some timepoint  $n$ , is marked by nasal formants; and
  - NC is followed by a segment that, from its beginning to some timepoint  $n$ , is marked by oral formants.

The MINDIST constraint in (13),  $\Delta$  BURST OR  $\Delta$  FQUALITY ( $S_2$ ), is violated when NC segments are unreleased and there is no following segment that hosts the appropriate nasal vs. oral formants. This constraint is disjunctive; the presence of one or the other of these cues is sufficient to satisfy it. The tableau in (14) illustrates. Candidates (14a–b), where the NC is released (a) or both are followed by the appropriate nasal vs. oral formants (b), satisfy (13). Candidate (14c), where the NC is unreleased, does not. Here and in what follows, stops in the input and output are released unless otherwise noted.

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<sup>4</sup>I know of no cases, however, where final Ns and NDs are in free variation. There is likely a reason for this. Given that NCs arguably involve more articulatory effort than either Ns or Cs (the velum does not move during an N or C) there must be sufficient reason, in contexts of neutralization, for NC to be the preferred variant. In initial position, the motivation is there: voicing contrasts are difficult to implement in initial position and voicing helps facilitate this (Kingston & Diehl 1994). In final position, it’s not clear what could motivate a speaker to expend the effort to produce an NC.

(14) Evaluation of MINDIST N–NC ( $\Delta$  BURST OR  $\Delta$  FQUALITY ( $S_2$ ))

	$\Delta$ BURST OR $\Delta$ FQUALITY ( $S_2$ )
a. and an	
b. anda anã	
c. and <sup>r</sup> an	*

The results of the typological survey, however, suggest that some languages place more restrictive requirements on the N–NC contrast. In Alawa (Sharpe 1972), for example, word-final stops are released but the word-final N–NC contrast is 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,  $\Delta$  *burst* is not sufficient;  $\Delta$  *formant quality* ( $S_2$ ) is necessary for the contrast to be licensed (15).

(15) MINDIST N–NC ( $\Delta$  FQUALITY ( $S_2$ )): assign one violation for every N–NC pair in the output that does not differ in the nasal vs. oral quality of the following segment, such that:

- N is followed by a segment that, from its beginning to some timepoint  $n$ , is marked by nasal formants; and
- NC is followed by a segment that, from its beginning to some timepoint  $n$ , is marked by oral formants.

As shown in (16), for  $\Delta$  FQUALITY ( $S_2$ ) to be satisfied, external cues must be present: NC’s oral release is not sufficient to distinguish it from N.

(16) Evaluation of  $\Delta$  FQUALITY ( $S_2$ )

	$\Delta$ FQUALITY ( $S_2$ )
a. and an	*
b. anda anã	
c. and <sup>r</sup> an	*

The status of a final N–NC segment contrast depends on the relative ranking of  $\Delta$  FQUALITY ( $S_2$ ) and IDENT[ $\pm$ nasal]-C, the latter of which is a faithfulness constraint that penalizes [ $\alpha$ nasal] output consonants whose input correspondents are not [ $\alpha$ nasal]. Concretely, I assume that Ns are [+nasal], Cs are [-nasal], and NCs are linked sequentially to both [+nasal] and [-nasal] (on sequential linking of features in nasal contours, see e.g. Anderson 1976, Poser 1979, Steriade 1993a). To keep things relatively simple, I assume that IDENT[ $\pm$ nasal]-C penalizes changes from any one of these three categories to any other.

(17) IDENT[ $\pm$ nasal]-C: assign one violation for each [ $\alpha$ nasal] output consonant whose input correspondent is not [ $\alpha$ nasal].

In languages where the N–NC segment contrast is licensed word-finally, IDENT[ $\pm$ nasal]-C dominates  $\Delta$  FQUALITY ( $S_2$ ): the N–NC contrast is preserved in spite of the absence of  $\Delta$  *formant quality* ( $S_2$ ). The crucial ranking necessary to generate a grammar in which the N–NC contrast is licensed both prevocally and finally is given below (18). An illustrative tableau follows (19); violations of  $\Delta$  FQUALITY ( $S_2$ ) are annotated with the output pair that violates it, and violations of IDENT[ $\pm$ nasal]-C are annotated with the input-output pair(s) that violate(s) it.<sup>5</sup>

<sup>5</sup>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.

As the analysis that follows is couched in the phonotactic component of Flemming’s (2008) Realized Input model, I assume that the inputs to the tableau in (19), and all that follow, are phonetically realized. For concreteness, I assume that vowels adjacent to nasal consonants, whether preceding or following, are allophonically nasalized in the phonetic realization component of the grammar; this nasalization is then reflected in the Realized Input. I assume also that nasal-adjacent vowels created in the output (e.g. through neutralization of an N–NC contrast, i.e. (19d,f)) are nasalized, presumably due to a high-ranked markedness constraint active in the phonotactic component of the grammar that requires nasal-adjacent vowels to be nasalized.<sup>6</sup> I assume that the requirement that nasal-adjacent vowels be nasalized, then, is one that is enforced by both the phonetic realization component of the grammar and the phonotactic component that follows it.

(18) Crucial ranking for permissive languages

IDENT[±nasal]-C  $\gg$   $\Delta$  FQUALITY (S<sub>2</sub>)

(19) IDENT[±nasal]-C  $\gg$   $\Delta$  FQUALITY (S<sub>2</sub>): word-final and intervocalic contrast

	$\tilde{a}n_1$ $\tilde{a}n\tilde{a}_3$	$\tilde{a}nd_2$ $\tilde{a}nda_4$	IDENT[±nasal]-C	$\Delta$ FQUALITY (S <sub>2</sub> )
a.	$\tilde{a}n_1$ $\tilde{a}n\tilde{a}_3$	$\tilde{a}nd_2$ $\tilde{a}nda_4$		* $\tilde{a}n_1$ – $\tilde{a}nd_2$
b.	$\tilde{a}n_1$ $\tilde{a}n\tilde{a}_3$	$\tilde{a}n_2$ $\tilde{a}nda_4$	*! $\tilde{a}nd_2 \rightarrow \tilde{a}n_2$	
c.	$\tilde{a}nd_1$ $\tilde{a}n\tilde{a}_3$	$\tilde{a}nd_2$ $\tilde{a}nda_4$	*! $\tilde{a}n_1 \rightarrow \tilde{a}nd_1$	
d.	$\tilde{a}n_1$ $\tilde{a}n\tilde{a}_3$	$\tilde{a}nd_2$ $\tilde{a}n\tilde{a}_4$	*! $\tilde{a}nda_4 \rightarrow \tilde{a}n\tilde{a}_4$	* $\tilde{a}n_1$ – $\tilde{a}nd_2$
e.	$\tilde{a}n_1$ $\tilde{a}nda_3$	$\tilde{a}nd_2$ $\tilde{a}nda_4$	*! $\tilde{a}n\tilde{a}_3 \rightarrow \tilde{a}nda_3$	* $\tilde{a}n_1$ – $\tilde{a}nd_2$
f.	$\tilde{a}n_1$ $\tilde{a}n\tilde{a}_3$	$\tilde{a}n_2$ $\tilde{a}n\tilde{a}_4$	*! $\tilde{a}nd_2 \rightarrow \tilde{a}n_2$ * $\tilde{a}nda_4 \rightarrow \tilde{a}n\tilde{a}_4$	
g.	$\tilde{a}nd_1$ $\tilde{a}nda_3$	$\tilde{a}nd_2$ $\tilde{a}nda_4$	*! $\tilde{a}n_1 \rightarrow \tilde{a}nd_1$ * $\tilde{a}n\tilde{a}_3 \rightarrow \tilde{a}nda_3$	

Candidates (19b–g) are all eliminated by IDENT[±nasal]-C, as at least one of the members of each candidate set evidences a mismatch between input and output corresponding consonants for the feature [±nasal]. In (19b), the contrast between  $\tilde{a}n_1$  and  $\tilde{a}nd_2$  is neutralized to  $\tilde{a}n_{1,2}$ ; in (19c), the contrast between  $\tilde{a}n_1$  and  $\tilde{a}nd_2$  is neutralized to  $\tilde{a}nd_{1,2}$ ; in (19d–e), the contrast between  $\tilde{a}n\tilde{a}_3$  and  $\tilde{a}nda_4$  is neutralized to  $\tilde{a}n\tilde{a}_{3,4}$  and  $\tilde{a}nda_{3,4}$ , respectively; and in (19f–g), both contrasts are neutralized (to either  $\tilde{a}n_{1,2}$  and  $\tilde{a}na_{3,4}$ , as in (19f), or  $\tilde{a}nd_{1,2}$  and  $\tilde{a}nda_{3,4}$ , as in (19g)). Thus (19a) is selected as optimal, despite its violation of  $\Delta$  FQUALITY (S<sub>2</sub>).

For restrictive languages, where prevocalic but not final N–NC is licensed, IDENT[±nasal]-C does not dominate  $\Delta$  FQUALITY (S<sub>2</sub>).<sup>7</sup> When CV transitions are absent, N–NC is neutralized. In all languages surveyed that neutralize the word-final N–NC contrast, the result of neutralization is

<sup>6</sup>These claims that nasal-adjacent vowels must be fully nasalized are made for expository purposes, and do not equal a claim that nasal-adjacent vowels are fully nasalized in all languages; see Chapter 3 on language-specific and contextual variation in degrees of coarticulatory nasalization.

<sup>7</sup>For languages in which final stops are released, we know that  $\Delta$  FQUALITY (S<sub>2</sub>)  $\gg$  IDENT[±nasal], as transitions are necessary to license N–NC even when  $\Delta$  *burst* would be present. In languages where final stops aren’t released, it’s difficult to determine the ranking between these two constraints: the oral component of an unreleased NC may not be perceptible, meaning that the N–NC contrast would violate  $\Delta$  BURST OR  $\Delta$  FQUALITY (S<sub>2</sub>) as well.

N: I assume that this is due to a low-ranked markedness constraint, \*NC, defined in (20).<sup>8</sup> I will assume here that \*NC is a constraint on articulatory effort: nasal contours involve not only velum lowering, velum raising, oral opening, and oral closing gestures – but also precise coordination among these.

(20) \*NC: assign one violation for each nasal+oral consonant sequence.

A possible ranking for restrictive languages is in (21); an illustrative tableau follows.

(21) Possible ranking for restrictive languages

$\Delta$  FQUALITY ( $S_2$ )  $\gg$  IDENT[ $\pm$ nasal]-C  $\gg$  \*NC

(22)  $\Delta$  FQUALITY ( $S_2$ )  $\gg$  IDENT[ $\pm$ nasal]-C  $\gg$  \*NC: intervocalic contrast only

	$\tilde{a}n_1$ $\tilde{a}n\tilde{a}_3$	$\tilde{a}nd_2$ $\tilde{a}nda_4$	$\Delta$ FQUALITY ( $S_2$ )	IDENT[ $\pm$ nasal]-C	*NC
a.	$\tilde{a}n_1$ $\tilde{a}n\tilde{a}_3$	$\tilde{a}nd_2$ $\tilde{a}nda_4$	*! $\tilde{a}n_1$ – $\tilde{a}nd_2$		**
b.	$\tilde{a}n_1$ $\tilde{a}n\tilde{a}_3$	$\tilde{a}n_2$ $\tilde{a}nda_4$		* $\tilde{a}nd_2 \rightarrow \tilde{a}n_2$	*
c.	$\tilde{a}nd_1$ $\tilde{a}n\tilde{a}_3$	$\tilde{a}nd_2$ $\tilde{a}nda_4$		* $\tilde{a}n_1 \rightarrow \tilde{a}nd_1$	**!
d.	$\tilde{a}n_1$ $\tilde{a}n\tilde{a}_3$	$\tilde{a}nd_2$ $\tilde{a}n\tilde{a}_4$	*! $\tilde{a}n_1$ – $\tilde{a}nd_2$	* $\tilde{a}nda_4 \rightarrow \tilde{a}n\tilde{a}_4$	*
e.	$\tilde{a}n_1$ $\tilde{a}nda_3$	$\tilde{a}nd_2$ $\tilde{a}nda_4$	*! $\tilde{a}n_1$ – $\tilde{a}nd_2$	* $\tilde{a}n\tilde{a}_3 \rightarrow \tilde{a}nda_3$	**
f.	$\tilde{a}n_1$ $\tilde{a}n\tilde{a}_3$	$\tilde{a}n_2$ $\tilde{a}n\tilde{a}_4$		* $\tilde{a}nd_2 \rightarrow \tilde{a}n_2$ *! $\tilde{a}nda_4 \rightarrow \tilde{a}n\tilde{a}_4$	
g.	$\tilde{a}nd_1$ $\tilde{a}nda_3$	$\tilde{a}nd_2$ $\tilde{a}nda_4$		* $\tilde{a}n_1 \rightarrow \tilde{a}nd_1$ *! $\tilde{a}n\tilde{a}_3 \rightarrow \tilde{a}nda_3$	*

Candidates (22a,d–e) are eliminated by fatal violations of  $\Delta$  FQUALITY ( $S_2$ ), as the contrast between the [n] in  $\tilde{a}n_1$  and the [nd] segment in  $\tilde{a}nd_2$  is not cued by  $\Delta$  *formant quality* ( $S_2$ ). Candidates (22f,g) are eliminated by gratuitous violations of IDENT[ $\pm$ nasal]-C, as they involve the neutralization of one or more contrasts. Between the remaining candidates, (22b) and (22c), (22b) is optimal as it incurs fewer violations of \*NC.

Across morpheme boundaries, the ranking in (21) predicts alternations, as seen in Sebikotane Saafi (Stanton 2012) (23) and Huave (San Francisco del Mar, Kim 2008) (24).<sup>9</sup> In both systems, root-final NC segments only surface as such when followed by a vowel-initial suffix.

(23) N/NC alternations in Saafi (Stanton 2012)

- a.  $\text{am} \rightarrow \text{amb-i}$  ‘to help’  $\rightarrow$  ‘helped’  
cf.  $\text{rAm} \rightarrow \text{rAm-i}$  ‘to walk’  $\rightarrow$  ‘walked’
- b.  $\text{ti:n} \rightarrow \text{ti:nd-en}$  ‘to walk’  $\rightarrow$  ‘walked’  
cf.  $\text{kam} \rightarrow \text{ka:n-i}$  ‘house’  $\rightarrow$  ‘the house’

<sup>8</sup>There is one exception I’m aware of, where N–NC neutralization yields an NC. In Yiddish, neutralization of word-final velar N–NC contrasts results in a velar NC. N–NC contrasts at other places of articulation, however, neutralize to N (Adam Albright, p.c.). I am unsure why the Yiddish velars are exceptional in this way.

<sup>9</sup>In the survey, Huave is classified as permissive: the San Francisco del Mar dialect allows final N–NC for NC affricates, and some speakers preserve final N–NC for plain NCs as well (Kim 2008, p.c.). The San Mateo dialect always allows final N–NC (Kim 2008:69, Noyer 2013).

- (24) N/NC alternations in Huave (Kim 2008, p.c.)
- a. t-a-him → t-a-himb-juφ      ‘s/he swept’ → ‘they swept’  
     cf. sa-ndjom → s-a-ndjom-an    ‘I want’ → ‘we (excl.) want’
  - b. n-a-jon → n-a-jond-an      ‘(that) I endure it’ → ‘(that) we endure it’  
     cf. m-a-jan → m-a-jan-af      ‘(that) s/he invites’ → ‘(that) they invite’

No ranking of the constraints introduced in this section –  $\Delta$  BURST OR  $\Delta$  FQUALITY ( $S_2$ ),  $\Delta$  FQUALITY ( $S_2$ ), IDENT[ $\pm$ nasal]-C, and \*NC – can generate a system in which N–NC is licensed word-finally only. As shown by (22d–e), systems with this property are harmonically bounded: they incur a violation of IDENT[ $\pm$ nasal]-C that does not result in the satisfaction of  $\Delta$  FQUALITY ( $S_2$ ). Since systems licensing N–NC word-finally only are unattested, this is a desirable result.

### 2.2.3 On burst amplitude and language-specific phonetics

A slightly different interpretation of the difference between the restrictive and permissive languages in section 2.2.1 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, but rather as a function of how perceptually distinct Ns and NC segments are. It could be the case, for example, that word-final stop releases are longer and louder in some of the surveyed languages than they are in others. Assuming that this acoustic difference would lead to  $\Delta$  *burst* being a more perceptible cue in languages where the release is more salient, the strength of the internal cues to N–NC will 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,  $\Delta$  *burst* on its own might not be sufficient to cue a final N–NC segment contrast, and word-final neutralization would result. In languages where stop releases are louder,  $\Delta$  *burst* on its own might be sufficient to cue a final N–NC segment contrast, 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 (25) classifies N–NC contrasts into three categories, according to the strength of the oral release. For Ns or unreleased NCs,  $\Delta$  *burst* = 0; for quietly released NCs,  $\Delta$  *burst* = 1; and for loudly released NCs,  $\Delta$  *burst* = 2.<sup>10</sup>

- (25) Release burst scale
- 0 N/NC' (N or unreleased NC)
  - 1 NC-1 (quietly released NC)
  - 2 NC-2 (loudly released NC)

To license word-final contrasts between Ns and loudly released NC segments, but not Ns and quietly released NC segments, a modification of the disjunctive constraint proposed in (13) is necessary. The revised definition in (26) requires N–NC contrasts to be cued by either  $\Delta$  *formant quality* ( $S_2$ ) or a  $\Delta$  *burst* of 2.

- (26) MINDIST N–NC ( $\Delta$  BURST-2 OR  $\Delta$  FQUALITY ( $S_2$ )): assign one violation for every N–NC pair in the output that does not differ in either (i) burst amplitude of 2 (by (25)) or (ii) the nasal vs. oral quality of the following segment, such that:
- a. N is followed by a segment that, from its beginning to some timepoint  $n$ , is marked by nasal formants; and

<sup>10</sup>I assume that the degree of release is derived in the phonetic realization component of the grammar, i.e. prior to the evaluations in (27–28).



- b. NC is followed by a segment that, from its beginning to some timepoint  $n$ , is marked by oral formants.

To satisfy (26), word-final N–NC contrasting pairs must differ in  $\Delta$  *burst* by 2, according to the scale in (25). In languages with quietly released final NC segments, (26) is not satisfied; the internal cues to N–NC when NC is quietly released are insufficient, and the contrast is neutralized (27). In languages with loudly released NC segments, however,  $\Delta$  *burst* is sufficient, and the word-final contrast is maintained (28). (I assume here that prevocalic N–NC contrasts would be licensed in both cases, as the presence of  $\Delta$  *formant quality* ( $S_2$ ), regardless of NC’s burst amplitude, is sufficient to satisfy the disjunctive MINDIST constraint.)

(27) Neutralization of word-final N–NC when NCs are quietly released (NC<sub>1</sub>)

	ãn    ãnd-1	$\Delta$ BURST-2 OR $\Delta$ FQUALITY ( $S_2$ )	IDENT[ $\pm$ nasal]-C	*NC
a.	ãn    ãnd-1	*!		*
b.	ãn    ãn		*	
c.	ãnd    ãnd-1		*	*!

(28) Preservation of word-final N–NC when NCs are loudly released (NC<sub>2</sub>)

	ãn    ãnd-2	$\Delta$ BURST-2 OR $\Delta$ FQUALITY ( $S_2$ )	IDENT[ $\pm$ nasal]-C	*NC
a.	ãn    ãnd-2			*
b.	ãn    ãn		*!	
c.	ãnd    ãnd-2		*!	*

The tableaux above provide an example of how the typology presented in section 2.1.1 could be analyzed by appealing to language-specific differences in stop release quality, rather than differences in the ranking of  $\Delta$  FQUALITY ( $S_2$ ) and IDENT[ $\pm$ nasal]-C (as in section 2.1.2). There is in fact independent evidence that appealing to the role of language-specific phonetic detail, i.e. the 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 distributional asymmetry between plain and affricated NCs can probably be attributed to the increased salience of the consonantal release: affricated releases are typically louder and longer than plain stop releases (see e.g. Wright 2004), rendering the internal cues to the affricated N–NC contrast more robust.<sup>11</sup> More generally, there is a growing amount of evidence that language-specific phonetic detail, including the presence or absence of stop releases, plays an important role in influencing phonological patterning (as discussed in Chapter 1.2; see e.g. Jun 1995, 2002; Zhang 2002; Kawahara 2006; Gallagher 2007; the present study; Flemming 2008b for a summary).

But because acoustic and perceptual studies of the surveyed languages appear to be nonexistent, and noncontrastive properties like the relative salience of stop releases are rarely discussed in descriptive grammars, it is difficult to explore this alternative any further. This lack of information regarding language-specific phonetic detail is my only 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 shown.

It is important to note that, while the analyses sketched here and in section 2.2.1 make different assumptions, they do not lead to different overall conclusions. Recall that the goals of the chapter are

<sup>11</sup>For other examples that make reference to burst amplitude in determining the distinctiveness of N–NC, see the discussion of final ND devoicing in section 2.2.5.

twofold: (i) to document cross-linguistic restrictions on the distribution of NCs, and (ii) 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 this chapter still stands: *constraints regulating the distribution of phonemic NCs are constraints on contrast*.

## 2.2.4 On $\Delta$ *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 can and cannot apply. I focus on the behavior of vowels following Ns, Ts, and ND segments: vowels following Ns and Ts can delete, but vowels following NDs cannot (29). (For more details regarding restrictions on apocope, see Hyslop 2001:39-42.)

- (29) Apocope in Lolovoli (Hyslop 2001:39-40)
- a. man      'laugh'      <mana>
  - b. k<sup>h</sup>at<sup>7</sup>      'speak'      <gato>
  - c. ma<sup>n</sup>da      'rotten'      <mada>

Why does this apocope process 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 NC segments can, are rare.<sup>12</sup> If apocope applied post-NC, the resulting final NCs would likely be unreleased. As discussed in section 2.1.1,  $\Delta$  *burst* and  $\Delta$  *formant quality* ( $S_2$ ) are two of the major cues to the contrast between Ns and ND segments; neither is available when final NDs are unreleased. A possible interpretation of the pattern in (29), then, 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 takes priority over apocope.<sup>13</sup>

To formalize this compromise, it is necessary to introduce a new constraint to motivate apocope. This constraint is \*V# (30), penalizing all words that end in a vowel. In addition, although I assume that word-final Lolovoli stops are unreleased in the Realized Input (i.e. the unreleased status of final stops is derived by the phonetic grammar), it is necessary to explain why the preferred repair to an indistinct word-final N-NC contrast is the retention of a word-final vowel, rather than deletion of the vowel and the addition of a word-final release. In other words, some duplication here is necessary: to derive the correct pattern, it must be assumed that there is some constraint, active in both the phonetic and the phonotactic components of Lolovoli's phonological grammar, that disprefers final released stops. I assume that this constraint is a markedness constraint, \*REL#, which penalizes word-final released stops.

- (30) \*V#: assign one violation for each candidate that ends in a vowel.

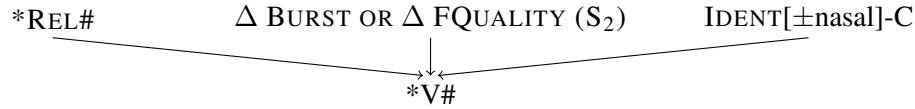
- (31) \*REL#: assign one violation for each word-final released stop.

<sup>12</sup>One exception is Wolof, where plain Cs aren't released, but geminates and NCs are. See the UCLA Phonetics Lab Archive (2007) for recordings. Another case is Boukhou Saafi (Mbodj 1983), where the description implies that word-final NCs but not single Cs are released following long vowels. Also, in South Efate (Thieberger 2006), word-final <sup>h</sup>d/ (a prenasalized alveolar stop with a trilled release) is released, even though final Cs and Ns are unreleased. But it is unclear whether <sup>h</sup>d/ is released simply by virtue of being an NC, or because trills are permitted word-finally and <sup>h</sup>d/ is, after all, half-trill. These cases aside, it is rare for a consonantal release to differentiate Cs and NCs.

<sup>13</sup>A question arises here as to whether or not a language would epenthesize a vowel after word-final NCs, in order to satisfy  $\Delta$  BURST OR  $\Delta$  FQUALITY ( $S_2$ ). The existence of such a case is predicted, but I know of none that exist.

As the desire to maintain a sufficiently distinct contrast between N and NC takes priority over apocope, we know that both  $\Delta$  BURST OR  $\Delta$  FQUALITY ( $S_2$ ) and IDENT[ $\pm$ nasal]-C dominate \*V#. In addition, as violation of \*V# (failure to apocope) is preferred to violation of \*REL# (addition of a word-final release), we know that \*REL# dominates \*V#. A summary of the ranking arguments necessary to generate (29) is below (32); a tableau follows (33).

(32) Necessary ranking arguments for Lolovoli



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

	ãñã ãnda	*REL#	$\Delta$ BURST OR $\Delta$ FQUALITY ( $S_2$ )	ID[ $\pm$ nas]-C	*V#
a.	ãñ ãnda				*
b.	ãñ ãnd	*!			
c.	ãñã ãnḍ		*!		*
d.	ãñ ãnḍ		*!		
e.	ãñã ãnda				**!
f.	ãñ ãñ			*!	

(33b) is eliminated due to a fatal violation of \*REL#, as the final stop in [and] is released. (33c–d) are eliminated due to fatal violations of  $\Delta$  BURST OR  $\Delta$  FQUALITY ( $S_2$ ), as the final stops are unreleased and the final Ns and NC segments do not differ in the nasal vs. oral quality of the following segment: in neither case is NC followed by oral formants. (33e) is eliminated due to an unnecessary violation of \*V#, and (33f), the neutralizing candidate, is eliminated by IDENT[ $\pm$ nasal]-C. (33a) 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–NC 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.<sup>14</sup> Steriade (1993a), in an effort to explain Feinstein’s (1979) generalization that final NC segments 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 NC segments as bipositional stops, with [nasal] (which Steriade assumes to be privative) 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. The present 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.  $\Delta$  *burst*,  $\Delta$  *formant quality* ( $S_2$ )). 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. So when NC’s final release is lost, many of the cues to the N–NC contrast go with it.

An empirical problem for Steriade’s proposal is that the status of final stop releases does not correlate directly with limitations on the distribution of final NCs (see also section 2.2.1): 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  $\Delta$  *formant quality* ( $S_2$ ) is necessary to license the N–NC contrast;  $\Delta$  *burst* alone is not sufficient ( $\Delta$  FQUALITY ( $S_2$ )  $\gg$  IDENT[ $\pm$ nasal]-C). In addition, there is a potential system in which final

<sup>14</sup>Some relevant cases include Acehnese (Durie 1985), Lua (Boyeldieu 1985), Gbaya Kara (Monino & Roulon 1972), Vouté (Guarisma 1978), and Wembawemba (Hercus 1986).

NT segments are unreleased, but final N–NT is maintained. In Neverver (Austronesian, Barbour 2012), [mb] and [ŋg] are licensed word-finally, but are often voiceless. For some younger speakers, these devoiced NCs are additionally unreleased. Barbour does not state that these younger speakers license an N–NC contrast, but this is implied by her transcriptions (see esp. Barbour p. 31).

The retention of final N–NT despite the lack of an oral release could be attributed to the fact that N–NT contrasts are likely to be bolstered by non-release-associated cues (e.g. large differences in N duration, a difference in V1 duration; see section 2.1.1). It is likely that the N–NT contrast in Neverver is marked by one of these additional cues, allowing it to be maintained when  $\Delta$  *burst* and  $\Delta$  *formant quality* ( $S_2$ ) is absent. But this is speculation, as there is no phonetic data available.

### 2.2.5 Contrast enhancement: final ND devoicing

In a number of systems, underlying ND segments are (or can be) realized as NT segments in word-final position. Languages with obligatory ND devoicing include Neverver (Barbour 2012), Kobon (Davies 1980), and Naman (Crowley 2006b); examples are in (34). Languages with optional devoicing include Avava (Crowley 2006a), Páez (Rojas Curieux 1998), and Tape (Crowley 2006d); examples are in (35).<sup>15</sup>

(34) Optional ND devoicing in Tape (Crowley 2006d:101)

- a. mi<sup>m</sup>b ~ mi<sup>m</sup>p ‘gecko’
- b. imimi<sup>n</sup>d ~ imimi<sup>n</sup>t ‘(s)he is sweating’

(35) Obligatory ND devoicing in Kobon (Davies 1980:24)

- a. gamp<sup>h</sup> ‘he does’ <gab>
- b. yant<sup>h</sup> ‘I’ <yad>

A possible – but likely incorrect – explanation for this phenomenon is that ND segments in these languages are phonetically enhanced 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 ND segments is not causally linked to the status of final voiced obstruents (section 2.2.1); 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 their production requires precise gestural coordination between the velum and the glottis: the velum must raise quickly after voicing ceases in order for the oral closure to be fully voiceless.<sup>16</sup> NT sequences are actively avoided and even eliminated in a number of languages (see Pater 1999, 2001 for a discussion in \*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, exclusively in word-final position?

<sup>15</sup>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 section 2.6.1.

<sup>16</sup>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 that are 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).

These two questions receive straightforward perceptual answers. Perhaps speakers expend additional articulatory effort to enhance N–ND when  $\Delta$  *formant quality* ( $S_2$ ) 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 section 2.1.1).<sup>17</sup> A potential explanation for why ND devoicing happens finally (and only finally) in these languages is that in this position,  $\Delta$  *formant quality* ( $S_2$ ) is absent. The idea is that speakers expend additional articulatory effort to render N–ND more distinct in precisely those environments where cues to the contrast are compromised (cf. Beguš 2015, Hamann & Downing 2015 for different takes on what motivates post-nasal devoicing).

As N–NT is likely distinguished by several cues that N–ND is not, there are several possible lines of analysis that we could pursue. One option is to claim that, for languages in which devoicing is obligatory, the necessary minimum acoustic distance between an N and an NC segment is either  $\Delta$  *formant quality* ( $S_2$ ) or a significant difference in release-associated cues.<sup>18</sup> In (36), N receives a value of 0 (no oral release cues), ND receives a value of 1 (weak oral release cues) and NT receives a value of 2 (strong oral release cues). For consistency with the previous subsections, I refer to this collection of release-associated cues as  $\Delta$  *burst*. (Note that the scale in (36) closely resembles the release burst scale employed in section 2.2.3, but with different referents for each number.)

- (36) Release burst scale
- |   |    |
|---|----|
| 0 | N  |
| 1 | ND |
| 2 | NT |

The original disjunctive constraint,  $\Delta$  BURST OR  $\Delta$  FQUALITY ( $S_2$ ), simply specified that Ns and NCs must be differentiated by  $\Delta$  *burst*. ND devoicing, however, suggests that some languages require a difference in  $\Delta$  *burst* of 2 when  $\Delta$  *formant quality* ( $S_2$ ) is not present ((37); see also (26)).

- (37) MINDIST N–NC ( $\Delta$  BURST-2 OR  $\Delta$  FQUALITY ( $S_2$ )): assign one violation for every N–NC pair in the output that does not differ in either (i) burst amplitude of 2 (by (36)) or (ii) the nasal vs. oral quality of the following segment, such that:
- a. N is followed by a segment that, from its beginning to some timepoint  $n$ , is marked by nasal formants; and
  - b. NC is followed by a segment that, from its beginning to some timepoint  $n$ , is marked by oral formants.

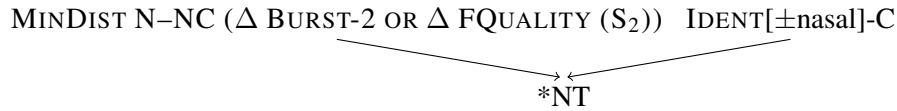
All languages with ND devoicing are permissive languages, as N–NC is preserved in the absence of  $\Delta$  *formant quality* ( $S_2$ ). The difference between these systems and the other permissive languages in section 2.2.1 is that when  $\Delta$  *formant quality* ( $S_2$ ) is absent, the N–NC contrast must be enhanced to survive. In other words, satisfaction of MINDIST N–NC ( $\Delta$  BURST-2 OR  $\Delta$  FQUALITY ( $S_2$ )) implies violation of an additional markedness constraint, \*NT, which penalizes the additional articulatory effort associated with the precise gestural coordination required to produce an NT. Because satisfying MINDIST N–NC ( $\Delta$  BURST-2 OR  $\Delta$  FQUALITY ( $S_2$ )) takes priority over avoiding NTs, we know that MINDIST N–NC ( $\Delta$  BURST-2 OR  $\Delta$  FQUALITY ( $S_2$ )) dominates \*NT. In addition,

<sup>17</sup>Does enhancing the N–ND contrast through devoicing to NT compromise 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 section 2.3.3 (and also Chapter 4) on interactions between N–NC and C–NC.

<sup>18</sup>Another possibility is that the additional cue could be a difference in V1 duration: vowels preceding NTs are shorter than vowels preceding Ns in a number of languages (see Kaplan 2008 and Katzir Cozier 2008 for various dialects of English, and Maddieson & Ladefoged 1993 for Sukuma).

as avoiding neutralization (i.e. violation of IDENT[±nasal]-C) is more important than avoiding NTs, IDENT[±nasal]-C must dominate \*NT. These ranking arguments are summarized below.

(38) Ranking summary for obligatory devoicing



Because MINDIST N–NC (Δ BURST-2 OR Δ FQUALITY (S<sub>2</sub>)) is highly-ranked, in word-final position where Δ *formant quality* (S<sub>2</sub>) is not present, underlyingly final NDs devoice. They do not however devoice in prevocalic position, where Δ *formant quality* (S<sub>2</sub>) is present and MINDIST N–NC (Δ BURST-2 OR Δ FQUALITY (S<sub>2</sub>)) is satisfied (39).

(39) Tableau for languages with obligatory final ND devoicing

	$\tilde{a}n_1$ $\tilde{a}nd_2$ $\tilde{a}n\tilde{a}_3$ $\tilde{a}nda_4$	Δ BURST-2 OR Δ FQUALITY (S <sub>2</sub> )	IDENT[±nasal]-C	*NT
a.	$\tilde{a}n_1$ $\tilde{a}nd_2$ $\tilde{a}n\tilde{a}_3$ $\tilde{a}nda_4$	*! $\tilde{a}n_1$ – $\tilde{a}nd_2$		
b.	$\tilde{a}n_1$ $\tilde{a}nt_2$ $\tilde{a}n\tilde{a}_3$ $\tilde{a}nda_4$			*
c.	$\tilde{a}n_1$ $\tilde{a}nt_2$ $\tilde{a}n\tilde{a}_3$ $\tilde{a}nta_4$			**!
d.	$\tilde{a}n_1$ $\tilde{a}n_2$ $\tilde{a}n\tilde{a}_3$ $\tilde{a}nda_4$		*! $\tilde{a}nd_2$ → $\tilde{a}n_2$	

In languages with variable devoicing, two opposing pressures conflict: the desire to have more perceptible contrasts (favoring N–NT, disfavoring N–ND) and the desire to avoid articulatory effort (favoring N–ND, disfavoring N–NT). There is thus variation between a N–ND, which is less distinct but easier to implement; and N–NT, which is more distinct but more difficult to implement.

As enhancement is not obligatory to maintain the final N–NC contrast in these languages, IDENT[±nasal]-C must dominate MINDIST N–NC (Δ BURST-2 OR Δ CV TRANS). In the tableau below (40), variation is modeled by the grammar’s inability to select a single optimal candidate. Again, as MINDIST N–NC (Δ BURST-2 OR Δ FQUALITY (S<sub>2</sub>)) is satisfied in intervocalic position, there is no variation when Δ *formant quality* (S<sub>2</sub>) is present.

(40) Tableau for languages with optional final ND devoicing

	$\tilde{a}n_1$ $\tilde{a}nd_2$ $\tilde{a}n\tilde{a}_3$ $\tilde{a}nda_4$	IDENT[±nasal]-C	Δ BURST-2 OR Δ FQUALITY (S <sub>2</sub> )	*NT
a.	$\tilde{a}n_1$ $\tilde{a}nd_2$ $\tilde{a}n\tilde{a}_3$ $\tilde{a}nda_4$		*! $\tilde{a}n_1$ – $\tilde{a}nd_2$	
b.	$\tilde{a}n_1$ $\tilde{a}nt_2$ $\tilde{a}n\tilde{a}_3$ $\tilde{a}nda_4$			*
c.	$\tilde{a}n_1$ $\tilde{a}nt_2$ $\tilde{a}n\tilde{a}_3$ $\tilde{a}nta_4$			**!
d.	$\tilde{a}n_1$ $\tilde{a}n_2$ $\tilde{a}n\tilde{a}_3$ $\tilde{a}nda_4$	*! $\tilde{a}nd_2$ → $\tilde{a}n_2$		

To capture the behavior of languages like Boukhou Saafi (Mbodj 1983) and Basáa (Hyman 2001),

where there is no final ND devoicing, the only necessary change is that \*NT must dominate MINDIST N–NC ( $\Delta$  BURST-2 OR  $\Delta$  FQUALITY ( $S_2$ )). The pressure to avoid NTs in these systems results in a lack of word-final enhancement, even though the articulatory simpler N–ND is perceptually less robust than is N–NT. This is illustrated in (41).

(41) Tableau for languages with no final ND devoicing

	$\tilde{a}n_1$ $\tilde{a}nd_2$ $\tilde{a}n\tilde{a}_3$ $\tilde{a}nda_4$	IDENT[ $\pm$ nasal]-C	*NT	$\Delta$ BURST-2 OR $\Delta$ FQUALITY ( $S_2$ )
a.	$\tilde{a}n_1$ $\tilde{a}nd_2$ $\tilde{a}n\tilde{a}_3$ $\tilde{a}nda_4$			* $\tilde{a}n_1$ – $\tilde{a}nd_2$
b.	$\tilde{a}n_1$ $\tilde{a}nt_2$ $\tilde{a}n\tilde{a}_3$ $\tilde{a}nda_4$		*!	
c.	$\tilde{a}n_1$ $\tilde{a}nt_2$ $\tilde{a}n\tilde{a}_3$ $\tilde{a}nta_4$		*!*	
d.	$\tilde{a}n_1$ $\tilde{a}n_2$ $\tilde{a}n\tilde{a}_3$ $\tilde{a}nda_4$	*! $\tilde{a}nd_2 \rightarrow \tilde{a}n_2$		

The proposed analysis of final NC effects offers an alternative explanation for Hyman’s (2001) observation that, in some languages, ND sequences undergo either D-nasalization (ND  $\rightarrow$  N) or post-nasal devoicing. While Hyman proposes that post-nasal devoicing is motivated by \*ND, a constraint active in the synchronic phonology, I interpret these processes as resulting from constraints on the contrast between N and ND. D-nasalization is neutralization (compelled when the final N–NC contrast cannot become sufficiently distinct, due either to high-ranked \*NT or  $\Delta$  FQUALITY ( $S_2$ )), and post-nasal voicing is enhancement (compelled when \*NT can be violated to satisfy  $\Delta$  BURST-2 OR  $\Delta$  FQUALITY ( $S_2$ )). While the languages highlighted by Hyman are unusual in that N–ND neutralization and enhancement occur prevocally, these facts alone are not problematic for the present analysis. What the present analysis predicts is that if ND devoicing or neutralization occurs prevocally (where cues to the contrast are stronger, as  $\Delta$  *formant quality* ( $S_2$ ) is present), it should also occur word-finally (where cues to the contrast are weaker, as  $\Delta$  *formant quality* ( $S_2$ ) is absent). In other words: the existence of neutralization or enhancement in some context where N–NC is more distinct implies its existence in all contexts where it is less distinct. The languages discussed by Hyman (2001) do not allow final Cs, and do not bear on this prediction.

There are however a couple of languages discussed by Beguš (2015) in which post-nasal devoicing has operated as a sound change both prevocally and word-finally. Forms demonstrating prevocalic and word-final post-nasal devoicing in Yaghnobi (Indo-European; Xromov 1972) are in (42), forms demonstrating prevocalic and word-final post-nasal devoicing in Konyagi are in (43) (Niger-Congo; Ferry 1991, Santos 1996, Merrill 2016). Following Beguš, I have provided cognates from related languages to confirm that post-nasal devoicing has occurred.

(42) Post-nasal devoicing in Yaghnobi (Xromov 1972:128, via Beguš 2015)

- a. yantum ‘wheat’  
cf. *Sogdian* *yandum*
- b. –ant ‘3rd pl.’  
cf. *Sogdian* –and

- (43) Post-nasal devoicing in Konyagi (Merrill 2016, via Beguš 2015)
- a. æ-jàmp ‘millet stalk’  
cf. *Bedik fāmb*
  - b. ì-fànk ‘be long’  
cf. *Bedik u-yáng*
  - c. ì-ntæw̃ ‘animal/spirit’  
cf. *Bedik gi-ndám*
  - d. ì-nkòt ‘pole’  
cf. *Bedik ge-ngót*

Crucially, while the two languages in (42–43) allow post-nasal devoicing both prevocally and word-finally, and the six languages under discussion in this section (Neverver, Kobon, Naman, Avava, Páez, and Tape) allow post-nasal devoicing only word-finally, there are no languages I am aware of in which post-nasal devoicing occurs only prevocally. Thus, as predicted by the contrast-based approach, the typologies of N–ND neutralization and N–ND enhancement mirror one another: the existence of either in prevocalic position (where N–ND is more distinct) implies its existence in word-final position (where N–ND is less distinct). For more discussion of the relationship between the typologies of neutralization and enhancement, see Chapters 3.3 and 5.

Regarding the observation that N–NT is likely a more distinct contrast when compared to N–ND, the discussion in this section raises the question as to whether or not any language licenses an N–NT contrast, but not an N–ND contrast, in the inventory component of the grammar (i.e. the segmental inventory contains Ns and NTs, but not NDs). Of the 50 languages surveyed for this chapter, all license an N–ND contrast, and an additional 4 license an N–NT contrast as well. In other words, no surveyed language licenses N–NT to the exclusion of N–ND (see also Maddieson 1984:67, who makes a similar point for the languages in UPSID). Exactly why the preference for the more distinct N–NT makes itself visible in the phonotactic but not the inventory component of the grammar is unclear.

## 2.3 Initial NCs and the C–NC contrast

Results from the cross-linguistic survey also verify the prediction in (11): initial C–NC asymmetrically implies postvocalic C–NC. Section 2.3.1 presents the results of the survey and discusses two apparent counterexamples. Section 2.3.2 presents an analysis of the typology, and section 2.3.3 discusses cases of variation that point to an interaction between the N–NC and C–NC contrasts.

The decision to focus on initial vs. postvocalic C–NC contrast was made due to the rarity of languages in the sample that allow stops to occur in postconsonantal position (e.g. *alta*). For languages with NCs that do allow stops in this position, however, the current analysis makes the prediction that if a language allows the C–NC contrast in postconsonantal position (where external cues are compromised), it must also allow that contrast in postvocalic position (where external cues are available). As far as I am aware, this prediction holds: Boukhou Saafi (Niger-Congo, Mbodj 1983), for example, licenses the contrast in both positions.

### 2.3.1 Survey results

Of the 50 languages surveyed, 42 license initial and postvocalic C–NC, 6 license postvocalic C–NC only, and 2 languages license initial C–NC only. Languages licensing C–NC postvocally and initially are ‘permissive’, and languages licensing C–NC postvocally only are ‘restrictive.’ The



languages classified as ‘other’ allow C–NC initially only; these appear to be problematic for the prediction in (11). Examples of each type of languages are below (44); see the appendix (section 2.6.1) for a full listing of all surveyed languages.

(44) Results for the C–NC contrast

Permissive (✓V_V, ✓#_V)	Restrictive (✓V_V, *#_V)	Other (*V_V, ✓#_V)
<i>42 languages, e.g.</i>	<i>6 languages, e.g.</i>	<i>2 languages</i>
Akoose (Hedinger 2008)	Kobon (Davies 1980)	Lua (Boyeldieu 1985)
Erromangan (Crowley 1998)	Mani (Childs 2011)	Mbum (Hagège 1970)
Ngambay (Vandame 1963)	Sinhalese (Feinstein 1979)	

Note that the six restrictive languages – Jabêm (Bradshaw & Czobor 2005), Kobon (Davies 1980), Mani (Childs 2011), Sinhalese (Feinstein 1979), Wembawemba (Hercus 1986), and Zarma (Tersis 1972) – are all languages that allow voiced stops in initial position, and that neutralize the D–ND contrast.<sup>19</sup> This is expected, as contrasts where C and NC share the same value for [ $\pm$ 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 [ $\pm$ voice] is consistent with the view that contrasts are neutralized in positions where they are most confusable. While there are other languages in which initial ND segments are variably realized as Ds, like Lolovoli (Hyslop 2001), Pérez (Rojas Curieux 1998), and Tape (Crowley 2006d), these are languages in which plain Ds are otherwise 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 problematic 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 (45), however, it becomes clear that the C–NC contrast is only one of many contrasts neutralized intervocalically. Below, parentheses indicate low frequency.<sup>20</sup>

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

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

I 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).<sup>21</sup> Generally speaking, voiced and voiceless obstruents are differentiated by closure duration, with longer duration cuing voicelessness (Massaro

<sup>19</sup> 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).

<sup>20</sup> I include only medial Cs attested in the native lexicon. See Boyeldieu 1985 for a discussion of loanword phonology.

<sup>21</sup> An alternative way to make sense of the Lua and Mbum facts would be to claim that they represent positional faithfulness effects, of the sort discussed at section 2.1.3. Even if this were the case, it would not undermine the main point of this chapter, which is that constraints on contrast have an *independent* effect on phonological patterns.

& 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 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 the effects of 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 the perception of the C–NC contrast alone. Although phonetic data is not available, we can speculate that the loss of NC segments in intervocalic position is not due to diminished perceptibility of C–NC, but rather that of N–NC: if the following vowel is too short to host  $\Delta$  *formant quality* ( $S_2$ ) of the appropriate duration, cues to the N–NC contrast in this position are potentially 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 (46). 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 (/ĩ/, /ã/, /ũ/). In non-initial syllables, the oral vowel inventory is reduced to /i/, /u/, /a/, 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 situation in which the initial syllable is lengthened and all others are reduced.<sup>22</sup>

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

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

Comparison of the N–NC survey results (section 2.1.1) 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 significant (Fisher’s exact,  $p < .001$ ), and correlates with Beddor & Onsuwan’s (2003) results. For the Ikalanga speakers in their study, N–NC is primarily dependent on  $\Delta$  *formant quality* ( $S_2$ ); in the survey, most languages neutralize N–NC word-finally, where  $\Delta$  *formant quality* ( $S_2$ ) is absent. By contrast, their results indicate that C–NC

<sup>22</sup>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 in initial position. In Mbabaram (Pama-Nyungan, Dixon 1991), for example, rhotics are allowed in intervocalic but not word-initial position.

is less dependent on  $\Delta$  *formant quality* ( $S_1$ ); in the survey, most languages maintain initial C–NC despite the absence of  $\Delta$  *formant quality* ( $S_1$ ). The observed difference in cue distribution between the two contrasts is directly reflected in the asymmetry of neutralization patterns documented here.

### 2.3.2 C–NC: constraints and analysis

The analysis of the C–NC typology is identical in spirit to the analysis of the N–NC typology presented in section 2.2.2. The two experimentally verified cues to the C–NC contrast are  $\Delta$  *nasal C formants* and  $\Delta$  *formant quality* ( $S_1$ ) (Beddor & Onsuwan 2003); I hypothesize that C–NC contrasts sharing the same value for  $[\pm\text{voice}]$  require the presence of at least one of these cues (47).

- (47) MINDIST C–NC ( $\Delta$  NASAL F OR  $\Delta$  FQUALITY ( $S_1$ )): assign one violation for every  $[\alpha\text{voice}]$  C–NC pair in the output that does not differ in either (i) nasal consonant formants or (ii) the nasal vs. oral quality of the preceding segment, such that:
- a. C is preceded by a segment that, from some timepoint  $n$  to its end, is marked by oral formants; and
  - b. NC is preceded by a segment that, from some timepoint  $n$  to its end, is marked by nasal formants.

$\Delta$  NASAL F OR  $\Delta$  FQUALITY ( $S_1$ ) is only violated when NC segments lack a nasal onset and the contrasting C–NC segments are not preceded by segments with the appropriate oral vs. nasal formants. Satisfaction of one disjunct is enough to satisfy the entire constraint; the presence of either  $\Delta$  *nasal C formants* or  $\Delta$  *formant quality* ( $S_1$ ) is sufficient.

The survey results suggest that some languages place more restrictive requirements on the distinctiveness of 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  $\Delta$  *formant quality* ( $S_1$ ) is an obligatory cue (48).

- (48) MINDIST C–NC ( $\Delta$  FQUALITY ( $S_1$ )): assign one violation for every  $[\alpha\text{voice}]$  C–NC pair in the output that does not differ in the nasal vs. oral quality of the preceding segment, such that:
- a. C is preceded by a segment that, from some timepoint  $n$  to its end, is marked by oral formants; and
  - b. NC is preceded by a segment that, from some timepoint  $n$  to its end, is marked by nasal formants.

The status of initial C–NC depends on the relative ranking of  $\Delta$  FQUALITY ( $S_1$ ) and IDENT $[\pm\text{nasal}]$ -C. For the permissive languages, IDENT $[\pm\text{nasal}]$ -C  $\gg$   $\Delta$  FQUALITY ( $S_1$ ), as the presence of  $\Delta$  *formant quality* ( $S_1$ ) is not necessary for C–NC to be licensed. An illustrative tableau follows (49).

(49) MAXCONTRAST  $\gg$   $\Delta$  VC TRANS: word-initial and intervocalic C–NC contrast licensed

	da <sub>1</sub> ada <sub>3</sub>	nda <sub>2</sub> ãnda <sub>4</sub>	IDENT[±nasal]-C	$\Delta$ FQUALITY (S <sub>1</sub> )
a.	da <sub>1</sub> ada <sub>3</sub>	nda <sub>2</sub> ãnda <sub>4</sub>		*da <sub>1</sub> –nda <sub>2</sub>
b.	da <sub>1</sub> ada <sub>3</sub>	da <sub>2</sub> ãnda <sub>4</sub>	*!nda <sub>2</sub> →da <sub>2</sub>	
c.	nda <sub>1</sub> ada <sub>3</sub>	nda <sub>2</sub> ãnda <sub>4</sub>	*!da <sub>1</sub> →nda <sub>2</sub>	
d.	da <sub>1</sub> ada <sub>3</sub>	nda <sub>2</sub> ada <sub>4</sub>	*!ãnda <sub>4</sub> →ada <sub>4</sub>	*da <sub>1</sub> –nda <sub>2</sub>
e.	da <sub>1</sub> ãnda <sub>3</sub>	nda <sub>2</sub> ãnda <sub>4</sub>	*!ada <sub>4</sub> →ãnda <sub>4</sub>	*da <sub>1</sub> –nda <sub>2</sub>
f.	da <sub>1</sub> ada <sub>3</sub>	da <sub>2</sub> ada <sub>4</sub>	*!nda <sub>2</sub> →da <sub>2</sub> *ãnda <sub>4</sub> →ada <sub>4</sub>	
g.	nda <sub>1</sub> ãnda <sub>3</sub>	nda <sub>2</sub> ãnda <sub>4</sub>	*!da <sub>1</sub> →nda <sub>2</sub> *ada <sub>4</sub> →ãnda <sub>4</sub>	

In the restrictive languages, where C–NC is licensed postvocally but not initially,  $\Delta$  FQUALITY (S<sub>1</sub>) dominates IDENT[±nasal]-C. The result of C–NC neutralization is always C, due to low-ranked \*NC. The tableau in (50) illustrates.

(50)  $\Delta$  VC TRANS  $\gg$  IDENT[±nasal]-C  $\gg$  \*NC: only intervocalic C–NC licensed

	da <sub>1</sub> ada <sub>3</sub>	nda <sub>2</sub> ãnda <sub>4</sub>	$\Delta$ FQUALITY (S <sub>1</sub> )	IDENT[±nasal]-C	*NC
a.	da <sub>1</sub> ada <sub>3</sub>	nda <sub>2</sub> ãnda <sub>4</sub>	*!da <sub>1</sub> –nda <sub>2</sub>		**
b.	da <sub>1</sub> ada <sub>3</sub>	da <sub>2</sub> ãnda <sub>4</sub>		*nda <sub>2</sub> →da <sub>2</sub>	*
c.	nda <sub>1</sub> ada <sub>3</sub>	nda <sub>2</sub> ãnda <sub>4</sub>		*da <sub>1</sub> →nda <sub>1</sub>	***!
d.	da <sub>1</sub> ada <sub>3</sub>	nda <sub>2</sub> ada <sub>4</sub>	*!da <sub>1</sub> –nda <sub>2</sub>	*ãnda <sub>4</sub> →ada <sub>4</sub>	*
e.	da <sub>1</sub> ãnda <sub>3</sub>	nda <sub>2</sub> ãnda <sub>4</sub>	*!da <sub>1</sub> –nda <sub>2</sub>	*ada <sub>3</sub> →ãnda <sub>3</sub>	**
f.	da <sub>1</sub> ada <sub>3</sub>	da <sub>2</sub> ada <sub>4</sub>		*nda <sub>2</sub> →da <sub>2</sub> *!ãnda <sub>4</sub> →ada <sub>4</sub>	
g.	nda <sub>1</sub> ãnda <sub>3</sub>	nda <sub>2</sub> ãnda <sub>4</sub>		*da <sub>1</sub> →nda <sub>1</sub> *!ada <sub>3</sub> →ãnda <sub>3</sub>	**

No permutation of these constraints can generate a system in which C–NC is licensed initially only. As shown by (50d–e), systems with this property are harmonically bounded: they incur a violation of IDENT[±nasal]-C that does not lead to satisfaction of  $\Delta$  FQUALITY (S<sub>1</sub>). This is a desirable prediction, as systems of this type, not amenable to an alternative explanation (e.g. the durational asymmetry in Lua and Mbum), are unattested.<sup>23</sup>

<sup>23</sup>Analyses for Lua and Mbum would assume that they are permissive languages (IDENT[±nasal]-C  $\gg$   $\Delta$  FQUALITY (S<sub>1</sub>)). The absence of intervocalic NCs is ultimately due to constraints motivating reduction, which outrank IDENT[±nasal]-C. The precise formulation of these additional constraints is not explored here.

As was discussed in relation to the N–NC contrast in section 2.2.3, it is possible that the relevant difference between the permissive and the restrictive C–NC systems is one of language-specific differences in phonetic implementation, rather than differences in the required perceptual distance between contrasting segments. For example, in some of the restrictive systems, the nasal portion of NC might be short, leading listeners to rely on the presence of  $\Delta$  *formant quality* ( $S_1$ ) to cue the C–NC contrast (see section 2.3.3). In these cases, C–NC might be neutralized word-initially, where  $\Delta$  *formant quality* ( $S_1$ ) is absent. It could also be that in some of the permissive systems, the nasal portion of NC is relatively long. In these languages, the perceptibility of C–NC would likely be only marginally impacted by the absence of  $\Delta$  *formant quality* ( $S_1$ ) due to the presence of strong internal cues, 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 are 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 chapter. Constraints on the distribution of phonemic NCs are constraints on contrast.

### 2.3.3 Variation and VC transitions

In Tukang Besi (Donohue 1999), the prenasalized affricate /ns/ has two allophonic variants. The first is a faithful realization with an oral closure, [ntʃ].<sup>24</sup> The second variant, a plain [s] preceded by a nasal vowel, is more common (51).

- (51) Variation in Tukang Besi (Donohue 1999:29)  
 ma<sup>n</sup>sa ~ māsa ‘silat (fighting arts)’

/s/ is possible word-initially, but /ns/ is not. Donohue speculates (p. 29) that this restriction on the distribution of /ns/ can be attributed to the “lack of a preceding vowel in word-initial position”. Re-framed slightly, Donohue’s speculation is that /s/ and /ns/ are not contrastive word-initially because the most reliable cue to the contrast,  $\Delta$  *formant quality* ( $S_1$ ), is absent in this position.

Additional diachronic evidence suggests that C–NC is unstable initially, in precisely the context where  $\Delta$  *formant quality* ( $S_1$ ) is absent. In Wolof (Ka 1994), while D–ND is licensed initially and postvocally, T–NT is licensed only postvocally. Ka’s explanation for the lack of initial NT segments 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 section 2.1.1 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 formants in a preceding segment. Perhaps N–NT in Wolof was more dependent on  $\Delta$  *formant quality* ( $S_1$ ) than N–ND, and was neutralized in initial position as a result. Some preliminary support for this analysis comes from the fact that, in Wolof, the nasal portion of ND appears to be longer than the nasal portion of NT: for the two tokens of [ʌmb] ‘to wrap’, the nasal averages 0.12s in duration. But for the two tokens of [lamp] ‘lamp’, the nasal consonant is absent; it can only be identified by the presence of nasalization in the preceding vowel (data from the UCLA Phonetics Archive). If these measurements are

<sup>24</sup>There is no contrast in Tukang Besi between prenasalized affricates and prenasalized fricatives, nor is such a contrast attested in any language (see Steriade 1993a). In Tukang Besi, /ns/ is usually pronounced with an oral occlusion ([nts]).

representative, the hypothesis that  $\Delta$  *formant quality* ( $S_I$ ) is a necessary cue to T–NT is potentially a plausible one.

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  $\Delta$  *formant quality* ( $S_I$ ) are absent. All else being equal, initial C–NC entails postvocalic C–NC.

## 2.4 Extending the predictions: segments vs. clusters

Up to this point, the major claim of this chapter has been that constraints on the distribution of prenasalized stops are constraints on contrast. But what if some of the languages included in the survey are misclassified, and what I have been referring to as NC segments are, in some cases, actually NC clusters? If we use different criteria for identifying NC segments – by following Riehl’s (2008:15) decision tree, for example – do the conclusions change?

In this section, I argue that the answer to this question is no. In section 2.4.1, I show that, regardless of whether we adopt a strictly phonotactic classification scheme, or Riehl’s more detailed decision tree, the implicational generalizations discovered in this chapter hold. In section 2.4.2, I present the results of a second survey and show that the implicational relationship documented for the N–NC segment contrast holds also for languages where NCs are obviously clusters: final N–NC implies prevocalic N–NC, regardless of NC’s phonological status. As I discuss in section 2.4.3, this is not a surprising result. It has been frequently documented in the literature that the phonological difference between NC segments and NC clusters does not contribute to a consistently observable difference in their phonetics (Maddieson & Ladefoged 1993, Ladefoged & Maddieson 1996; cf. Riehl 2008, Cohn & Riehl 2012).

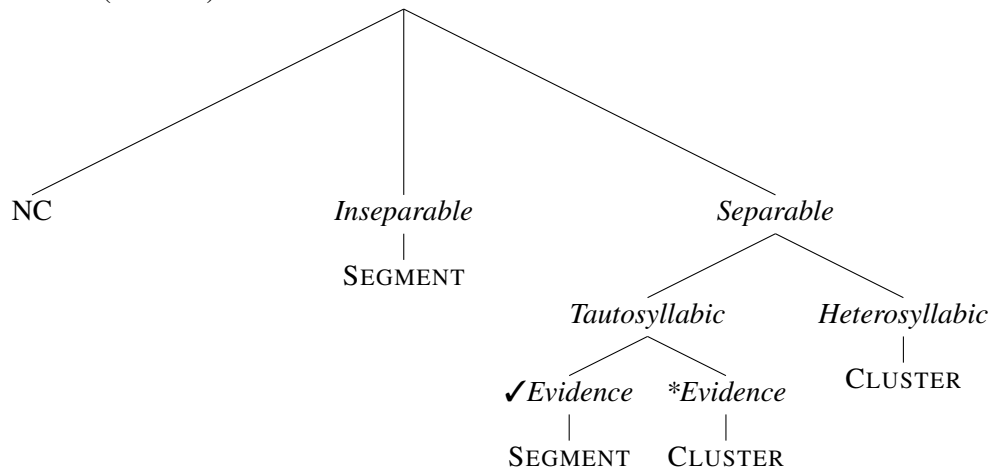
The main point of this section, then, is that it does not matter for our purposes whether NCs are segments or clusters. The same implicational generalizations hold.

### 2.4.1 Riehl (2008) and separability

Riehl (2008:15) presents a method for classifying NCs as segments or clusters that differs from the diagnostic employed in the present chapter. While I have followed the fairly standard assumption that NCs should be treated as segments if they are licit in environments where other clusters (or sonority-violating clusters) are not (see e.g. Anderson 1976:331), Riehl (2008:15) advocates a different approach, in which the segment or cluster status of an NC sequence is determined by following a three-step process.

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 appear 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 segments. If the NC sequence is separable, the next step is to determine properties of its syllabification. If the NC sequence is heterosyllabic (i.e.  $a_\sigma m b a_\sigma$ ), it must be a cluster; if it is tautosyllabic (i.e.  $a_\sigma m b a_\sigma$ ), it is likely a cluster, unless there is additional 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 segmental analysis include pre-C lengthening phenomena (though cf. Downing 2005) and cluster phonotactics. Riehl’s (2008:15) decision tree, with small modifications, is replicated in (52).

(52) 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 (52), does the conclusions of this chapter change? To answer this question, I separated the surveyed languages into two categories: “obviously segments” and “not obviously segments.” The first category, “obviously segments”, consists of all languages in which at least one NC sequence is inseparable, and therefore unary, according to Riehl. The second category, “not obviously segments”, consists of all languages in which all NC sequences are separable. I did not make further distinctions within this latter 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 section 2.6.1.

Looking at the patterns of N–NC neutralization, we find that the same implicational generalization holds across the “obviously segments” (53) and “not obviously segments” (54) 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 segments” category, while most of the restrictive languages fall into the “not obviously segments” 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 segments” category are restrictive is that some of them are in fact languages with NC clusters, and the ban on final NCs just represents part of a larger ban on final clusters.

(53) N–NC for languages with “obviously segment” NCs

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

(54) N–NC for languages with “not obviously segment” NCs

Permissive (✓ <sub>_V</sub> , ✓V <sub>_#</sub> )	Restrictive (✓ <sub>_V</sub> , *V <sub>_#</sub> )	Other (* <sub>_V</sub> , ✓V <sub>_#</sub> )
7 languages, e.g. Kobon (Davies 1980) Makaa (Heath 2003) Tobati (Donohue 2002)	23 languages, e.g. Acehnese (Durie 1985) Lua (Boyeldieu 1985) Ngambay (Vandame 1963)	0 languages

For the C–NC contrast, too, the same implicational generalization holds across both groups of languages. For languages with inseparable NCs (55), postvocalic C–NC always implies initial C–NC; for languages with separable NCs (56), the same generalization holds, with the exceptions of Lua and Mbum (see section 2.3.1). While slightly more “not obviously segments” than “obviously segments” languages are permissive, this is not a significant asymmetry (Fisher’s exact,  $p = .38$ ).

(55) C–NC for languages with “obviously segment” NCs

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

(56) C–NC for languages with “not obviously segment” NCs

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

In both groups, more languages license initial C–NC than final N–NC. This asymmetry is significant for both groups (Fisher’s exact;  $p = .019$  for “obviously segments”;  $p < .001$  for “not obviously segments”). 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 segments” or “not obviously segments” does not matter.

## 2.4.2 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 (in other words, there is no indication that they behave phonologically as a single segment). The survey was not intended to be exhaustive or typologically balanced. A prerequisite for inclusion was that the language allow at least some kind of final sonorant-stop cluster, so that the absence of final NC clusters is a potentially significant gap. As none of the surveyed languages allow initial NCs, the prediction that initial C–NC should imply postvocalic C–NC is vacuously true. In all 25 languages surveyed, N–NC is licensed prevocally; in 19, N–NC is also licensed word-finally. Examples are in (57); the full list is in the appendix (section 2.6.2).<sup>25</sup>

(57) N/NC in languages with clear NC clusters

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

<sup>25</sup>The number of languages surveyed here is fewer, but the gap is still meaningful. Results from a Monte Carlo simulation (composed of 10,000 iterations) indicate that we expect the “Other” category to contain 0 languages less than .0001% of the time; of the 10,000 iterations performed, none resulted in the “Other” category having a value of 0. Thus it is unlikely that the observed value of 0 is due to chance.



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 prevocally. In American English, for example, while N–NT and N–ND are licensed prevocally 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 prevocally, but only N–NT is licensed word-finally. Beyond this, there are often additional complications (see e.g. Mascaró 1978:80ff on Catalan), but the important point here is that there are no cases in which an N–NC contrast is maintained word-finally but neutralized prevocally.

What these results suggest, then, is that the implicational generalizations established in sections 2.2 and 2.3 regarding the distribution of the N–NC and C–NC contrasts hold not just for NC segments, but also for NC clusters: the implicational laws governing the distribution of NCs, whether segments or clusters, are one and the same.

### 2.4.3 NC segments vs. NC clusters

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, the duration of the entire sequence is roughly split between Ns and Ts (see e.g. Cohn & Riehl 2012 and references there). In addition, languages where NCs are clusters often exhibit anticipatory nasal coarticulation (see Jeong 2012 for an overview), as do languages where NCs are segments. Finally, NC clusters do not appear to be gesturally 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 gestural coordination.

In fact, the only phonetic factor that has been claimed to differentiate NC segments from NC clusters is the overall duration of the NC sequence. The claim is the following: for a given language, NCs should be classified as segments if the overall duration of the NC is roughly equivalent in duration to a plain nasal consonant in that same language. If however the NC is substantially longer than a plain nasal consonant, then the NC should be classified as a cluster (Riehl 2008, Cohn & Riehl 2012). While this is claimed to be a universally present difference between NC segments and NC clusters, the claim has only been investigated for small number of Austronesian languages, and even within this language family there are cases where its predictions do not appear to hold. This is illustrated below through a brief review of Adisasmito-Smith's (2004) investigation into Javanese and Indonesian phonetics and phonology.

In Javanese, phonological evidence suggests that NC sequences pattern with single segments (Adisasmito-Smith 2004). Word-initial NC sequences, created through prefixation of the placeless nasal N– (see Adisasmito-Smith 2004:258), are the only type of word-initial sonority-violating clusters permitted. Word-internally, the only licit clusters are stop + liquid, or NC + liquid. Distributionally speaking then, in Javanese, NC sequences appear to pattern more like segments than

like clusters. Additional evidence that NC sequences are treated by the phonology as segments comes from a vowel centralization process that targets vowels in closed syllables (Adisasmito-Smith 2004:260-264). In closed syllables, all vowels are realized as lax (e.g. [ɪ], [ʊ], [a]); in open syllables, all vowels are realized as tense (e.g. [i], [u], [ɔ]). Examples of centralization before word-final codas (58) and word-medial CC clusters (59) illustrate the process: note that in (58c) and (59c), an additional vowel harmony process causes the [a] in the initial open syllable to harmonize with the [a] in the final syllable.

- (58) Vowel centralization before word-final Cs (Adisasmito-Smith 2004:261)
- a. /titip/ → [titɪp] ‘leg’ cf. /titi/ → [titi] ‘meticulous’
  - b. /kukur/ → [kukʊr] ‘scratch’ cf. /kuku/ → [kuku] ‘finger’
  - c. /tatap/ → [tatap] ‘bump’ cf. /tata/ → [tɔtɔ] ‘arrange’
- (59) Vowel centralization before word-medial CCs (Adisasmito-Smith 2004:262)
- a. /p<sup>h</sup>ukti/ → [p<sup>h</sup>ʊkti] ‘evidence’ cf. /p<sup>h</sup>ukit/ → [p<sup>h</sup>ʊkɪt] ‘hill’
  - b. /sirna/ → [sɪrɔ] ‘disappear’ cf. /siram/ → [sɪram] ‘bathe’
  - c. /darma/ → [darmɔ] ‘duty’ cf. /damar/ → [damar] ‘k.o. tree’

The crucial point here is that, with respect to the vowel centralization process, NC sequences behave like single segments – and crucially unlike CC clusters. As shown in (60), vowels before NC sequences are uniformly realized as tense vowels, like vowels in open syllables (as shown in a–c) and unlike vowels in closed syllables (compare the final vowels of (60c–d)). (Note that while the following examples involve only velar NCs, NCs at other places of articulation behave identically.)

- (60) No vowel centralization before NC sequences (Adisasmito-Smith 2004:262-263)
- a. /tiŋk<sup>h</sup>i/ → [tiŋk<sup>h</sup>i] ‘louse’
  - b. /tuŋk<sup>h</sup>u/ → [tuŋk<sup>h</sup>u] ‘wait’
  - c. /liŋg<sup>h</sup>is/ → [liŋg<sup>h</sup>is] ‘machete’
  - d. /muŋkur/ → [muŋkʊr] ‘face down’

In Indonesian, by contrast, phonological evidence suggests that NC sequences should be treated as clusters. While Javanese freely allows word-initial NC sequences, Indonesian does not, and word-initial NCs appear only in a small set of words (Adisasmito-Smith 2004:268 cites three: *nga?* and *nda?* ‘no’, as well as *mbak* ‘title for women’, the last of which is a borrowing from Javanese.). This ban on initial NC sequences goes hand-in-hand with a more general ban on word-initial sonority-violating clusters. And while there is evidence from segmental alternations in Javanese that NC sequences pattern with segments, there is no evidence for this in Indonesian. Thus it seems prudent to treat NC sequences in Javanese as clusters, as there is no evidence (distributional or otherwise) to suggest that they should be treated as segments.

But although the phonology of NC sequences differs dramatically from Javanese to Indonesian, in both languages the duration of NC sequences is significantly more than the duration of their component parts, Ns and Cs (see Adisasmito-Smith 2004:307 for a summary). This is not what is expected given the hypothesis of Riehl (2008) and Cohn & Riehl (2012), in which a difference in NC’s phonological status should contribute to a difference in its overall duration. If their hypothesis were correct, we would expect for the duration of an NC sequence in Javanese to be roughly equivalent to the duration of a single segment. Faced with this discrepancy, we could reach one of two possible conclusions: either that what appear to be NC segments in Javanese are actually clusters, or that a difference in NC’s phonological status does not lead to a difference in its phonetics.<sup>26</sup>

<sup>26</sup>Neither Riehl (2008) nor Cohn & Riehl (2012) discuss this case, nor is it clear what they would conclude from it.

The first conclusion is undesirable: if the evidence presented above is not sufficient to conclude that Javanese NCs are treated as segments by the phonology, then what is? Riehl (2008) provides no specific diagnostics: on p. 24, she writes that “if NC sequences appear to be treated as single segments by the phonology, in contrast to clear consonant clusters, there may be a case for unary segmenthood.” In the above discussion of vowel centralization, we have seen clear evidence that Javanese NCs pattern as single segments, not clusters. The only reasonable conclusion to reach, then, is that whatever the phonological difference between NC segments and NC clusters may be, it does not lead to a consistent difference in their phonetics. This is the conclusion reached by the majority of other authors.

So, then, if the phonetic properties of NCs are not dependent on their phonological status, then the distribution of cues to the contrasts they enter into – here N–NC and C–NC – should not depend on it either. And if cue distribution does not depend on the representational status of an NC, then the difference between segment and cluster NCs should be completely irrelevant to cue-based theories of phonotactics. In other words, given that there are no consistent differences in the phonetics of NC segments and NC clusters, a cue-based approach to phonotactics predicts that we should find no consistent differences in their distribution. The fact that this is the correct prediction is supporting evidence for the general approach advocated in this thesis.

Before closing, I would like to acknowledge a larger question looming here. As suggested above, whatever factor leads to a representational difference between NC segments and NC clusters appears to play no role in the implicational generalizations that govern the distribution of N–NC and C–NC contrasts. Given this conclusion, it is valid to ask: if the difference between NC segments and NC clusters is not relevant to the distributional properties of the contrasts they enter to, then what is this representational distinction relevant to? Would it be possible to do away with this distinction altogether, perhaps by analyzing all NC sequences as clusters?

It is not clear to me, at present, what the answer is. While the move to eliminate a representational distinction between NC segments and NC clusters has precedent (Herbert 1986), and would provide a natural and satisfying answer to some questions that have been raised in the literature – why, for example, if NC segments and NC clusters are separate phonological entities, does there not appear to be a single language in which the two contrast (see Riehl 2008:64-69 for a recent review)? – it would also raise others. As will be discussed more fully in Chapter 3, in some languages NC sequences arise only as allophonic variants of other segments. Do we want to claim that these allophonic NCs and the NC clusters of English, for example, have the same representational status? In addition, if there is no representational distinction between NC segments and NC clusters, how do we explain why NC sequences have the distributional properties of segments in some languages, and clusters in others? For now I leave these questions open.

## 2.5 Discussion

So far, this chapter has argued that a contrast-based approach to phonotactics is sufficient to account for the distributional properties of the N–NC and C–NC contrasts. But it is necessary to ask: is there an alternative? Can the implicational generalizations observed here be explained without adopting a model of the grammar that requires us to make reference to constraints on contrast?

We have already seen, in section 2.1.3, that a syllable-based approach to NC distribution does not yield an obvious account for the observed implicational generalizations. While the fact that final NC implies prevocalic NC can potentially be explained by appealing to the distribution of NC with respect to different syllabic positions – coda NC is more marked than onset NC – the fact that

postvocalic NC implies initial NC is more difficult to explain. In the following section, I consider an additional alternative that appears to be capable of accounting for both of these generalizations: that the loss of word-initial C–NC and word-final N–NC contrasts in some languages is not the result of any synchronic pressure, but rather the loss of relatively indistinct contrasts over time due to learner misapprehension (following e.g. Ohala 1981, Blevins 2004, Moreton 2008). Under this alternative, perception of contrasts plays no role in the synchronic phonological grammar, but rather has the potential to shape phonological systems diachronically.

### 2.5.1 A historical approach

It is possible to account for the implicational generalizations that govern the distribution of the N–NC and C–NC contrasts by appealing to the hypothesis that the less distinct a contrast, the more likely it is to be lost over time. To illustrate, we will consider how the system in (61), in which the N–NC and C–NC contrasts are licensed in intervocalic position only (as in Sinhalese, e.g. Feinstein 1979), could be derived.

- (61) Language with C–NC and N–NC contrasts at all positions
- a. *Word-initial position*: \*da, ✓na, ✓nda
  - b. *Intervocalic position*: ✓ada, ✓ana, ✓anda
  - c. *Word-final position*: ✓ad, \*an, ✓and

Let us suppose that, in its original state, the language in (61) originally licensed N–NC and C–NC contrasts at all three positions: word-initial, intervocalic, and word-final. Over time, however, final NCs may be misperceived as Ns (due to the lack of  $\Delta$  *formant quality* ( $S_2$ ) in this position, causing the oral portion of NC to be less well-cued), resulting in neutralization of the word-final N–NC contrast. In addition, initial NCs may be misperceived as Cs (due to the lack of  $\Delta$  *formant quality* ( $S_1$ ) in this position, causing the nasal portion of NC to be less well-cued), resulting in neutralization of the word-initial C–NC contrast. As  $\Delta$  *formant quality* ( $S_2$ ) is available to cue prevocalic N–NC contrasts, and  $\Delta$  *formant quality* ( $S_1$ ) is available to cue postvocalic C–NC contrasts, both of these contrasts would be maintained. These diachronic developments would yield the system in (61); a summary of the proposed trajectory is provided in (62).

(62) Proposed historical trajectory resulting in (61)

Reported neutralization trajectory resulting in (S1)		
[na]	→	[na]
[da]	→	[da] <i>Δf. <b>quality</b> (S<sub>1</sub>) not available in initial position. As a result, initial C–NC contrast is neutralized.</i>
[nda]	→	
[ana]	→	[ana]
[ada]	→	[ada]
[anda]	→	[anda]
[ad]	→	[ad]
[an]	→	[an] <i>Δf. <b>quality</b> (S<sub>2</sub>) not available in final position. As a result, final N–NC contrast is neutralized.</i>
[and]	→	

If we assume that less distinct contrasts are more likely to be neutralized over time, and that the neutralization of less distinct contrasts implies the neutralization of more distinct contrasts, then the implicational generalizations presented in this chapter can be derived: neutralization of final N–NC (where  $\Delta$  **formant quality** (S<sub>1</sub>) is not available) implies neutralization of prevocalic N–NC (where it is), and neutralization of initial C–NC (where  $\Delta$  **formant quality** (S<sub>2</sub>) is not available) implies neutralization of postvocalic C–NC (where it is).

What is harder to derive, however, are the demonstrably synchronic effects that have been documented in this chapter. Take, for example, the instances of final ND devoicing discussed in section 2.2.5. As analyzed in section 2.2.5, final ND devoicing is a form of enhancement: in final position, a potentially confusable N–ND contrast is rendered more distinct by devoicing the ND. Enhancement is difficult to derive in frameworks that do not acknowledge the relevance of contrast to the synchronic grammar, as most enhancement phenomena cannot be plausibly analyzed as a result of neutralization of indistinct contrasts over time (for more discussion, see Chapter 3.4.3; though cf. Beguš 2015 on diachronic paths to post-nasal devoicing, and Boersma & Hamann 2008, Wedel 2012 on deriving diachronic enhancement). In addition, the apocope pattern attested in Lolovoli (section 2.2.4) is potentially difficult for a theory in which the role of contrast is relegated to sound change: it is unclear what set of historical developments could have led to the generalization that apocope targets post-T and post-N vowels, but not post-ND vowels. While it would be possible to capture the observed distribution without constraints on contrast by appealing to the context-sensitive markedness constraint \*ND#, in order for this constraint to block apocope, the speaker would have to have some knowledge that \*ND# would be violated were apocope to apply. This method of satisfying \*ND# entails a degree of awareness that theories of innocent misapprehension generally do not attribute to individual speakers.

In sum, with a theory that treats contrast exclusively as a factor that shapes a language’s diachronic development (and not a primitive of the synchronic grammar), it is possible to account for the broad implicational generalizations that govern the distribution of the N–NC and C–NC con-

trasts. The synchronic effects discussed in sections 2.2.4 and 2.2.5, however, are more difficult to account for. In Chapter 3, we will see that the diachronic account outlined here runs into further problems when attempting to account for an additional enhancement phenomenon, *environmental shielding* (see esp. Herbert 1986), that results in the appearance of allophonic nasal-stop sequences.

### 2.5.2 Summary

This chapter has argued 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, this chapter provides substantial evidence for the hypothesis that phonemic contrasts are first licensed in contexts of maximum perceptibility, and first neutralized in contexts where relevant cues to the contrasts are absent (Steriade 1997).

Additionally, this chapter provides evidence in support of broader predictions of a contrast-based approach to phonotactics. Given an insufficiently distinct N–NC contrast, a language has in principal two possible responses: neutralization of the contrast (which avoids the problem of distinctiveness altogether), or enhancement of the contrast (which renders the contrast sufficiently distinct). A contrast-based account thus predicts that the typologies of neutralization and enhancement should mirror one another: if some contrast  $x$ – $y$  is neutralized or enhanced in some context  $C_1$ , it should be neutralized or enhanced in all contexts  $C_n$  in which  $x$ – $y$  is less distinct. As noted by Flemming (2008a), however, evidence in support of this prediction is lacking, as enhancement phenomena are only infrequently reported. The fact that the typologies of N–NC neutralization and N–NC enhancement parallel each other, then, provides significant support for the contrast-based account’s analysis of neutralization and enhancement as two different responses to the same problem. More substantial support along these lines follows in Chapter 3.

## 2.6 Appendix A: lists of languages surveyed

### 2.6.1 Languages allowing unary NCs and final stops

This appendix contains a list of all surveyed languages in which NCs appear to pattern with segments, each language annotated with information concerning its consonantal phonotactics. A key necessary to interpret the information about the consonantal phonotactics is provided in (63):

(63) Key for section 2.6.1

R	Restrictive (N–NC: licensed prevocally only; C–NC: licensed postvocally only)
P	Permissive (N–NC: licensed prevocally and word-finally; C–NC: licensed postvocally and word-initially)
O	Other (N–NC: licensed word-finally only; C–NC: licensed initially only)
Shaded	Segment present in the inventory
Unshaded	Segment not present in the inventory
[D]	Noted variation between Ts and Ds, either free or allophonic (see source for details)
(M)	Marginal phoneme
?D	Implosives

In addition, to save space, many of the language family names have been abbreviated. The abbreviations are as follows: Aust. (Austronesian), NC (Niger-Congo), AA (Afro-Asiatic), TNG (Trans-New Guinea), PN (Pama-Nyungan), IE (Indo-European), NS (Nilo-Saharan). The list of surveyed languages, in Table 2.2, begins below.

Table 2.2: List of surveyed NC segment languages

Basic information	Contrasts		Inventory						Type (Sect. 2.4)
Language (Family) Source	N–NC	C–NC	D	T	N	ND	NT	?D	Separable?
Abun (Isolate) Berry & Berry 1999	R	P							Yes
Acehnese (Aust.) Durie 1985	R	P							Yes
Akoose (NC) Hedinger 2008	R	P							Yes
Alawa (Arnhem) Sharpe 1972	R	P	[D]						No
Avava (Aust.) Crowley 2006a	P	P							No
Basáa (NC) Hyman 2001	P	P	[D]						No
Cèmuhî (Aust.) Lynch 2002a	R	P							No
Erromangan (Aust.) Crowley 1998	P	P							No

Basic information	Contrasts		Inventory						Type
Language (Family) Source	N-NC	C-NC	D	T	N	ND	NT	?D	Sep.?
Fe'-Fe'-Bamileke (NC) Hyman 1972	R	P							Yes
Gbaya Kara (NC) Monino & Roulon 1972	R	P							Yes
Gbeya (NC) Samarin 1966	R	P							Yes
Guruntum (AA) Haruna 2003	R	P							Yes
Hdi (AA) Frajzyngier 2002	R	P							Yes
Huave (isolate) Kim 2008	P	P	(M)						No
Jabêm (Aust.) Bradshaw & Czobor 2005	R	R							Yes
Kaulong (Aust.) Ross 2002a	R	P							No
Kele (Aust.) Ross 2002b	R	P	[D]						Yes
Kobon (TNG) Davies 1980	P	R							Yes
Lolovoli (Aust.) Hyslop 2001	R	P							No
Lua (NC) Boyeldieu 1985	R	O							Yes
Makaa (NC) Heath 2003	P	P							Yes
Mani (NC) Childs 2011	P	R							Yes
Mara (Arnhem) Heath 1981	R	P							Yes
Mbabaram (PN) Dixon 1991	R	P	[D]						No
Mbuko (AA) Smith & Gravina 2010	R	P							Yes
Mbum (NC) Hagège 1970	R	O							Yes
Mina (AA) Frajzyngier & Johnston 2005	R	P							Yes
Muyang (AA) Smith & Gravina 2010	R	P							Yes
Mwotlap (Aust.) Crowley 2002	R	P							No



Basic information	Contrasts		Inventory						Type
Language (Family) Source	N–NC	C–NC	D	T	N	ND	NT	?D	Separable?
Naman (Aust.) Crowley 2006b	P	P							No
Nese (Aust.) Crowley 2006c	P	P							No
Nevei (Aust.) Crowley 2006c	P	P							No
Neverver (Aust.) Barbour 2012	P	P							No
Ngambay (NC) Vandame 1963	R	P							Yes
Nizaa (NC) Endresen 1991	R	P							Yes
Paamese (Aust.) Crowley 1982	P	P							No
Páez (Isolate) Rojas Curieux 1998	P	P							No
Saafi, Boukhou (NC) Mbodj 1983	P	P							Yes
Saafi, Sebikotane (NC) Stanton 2012	R	P							Yes
Sinhalese (IE) Feinstein 1979	R	R							Yes
South Efate (Aust.) Thieberger 2006	P	P	[D]						No
Tape (Aust.) Crowley 2006d	P	P							No
Tobati (Aust.) Donohue 2002	P	P							Yes
Tunen (NC) Dugast 1971	P	P							Yes
Ura (Aust.) Crowley 1999	R	P							No
Vouté (NC) Guarisma 1978	R	P							Yes
Wembawemba (PN) Hercus 1986	R	R	[D]						No
Western Dani (TNG) Barclay 2008	R	P	[D]						Yes
Wolof (NC) Ka 1994	P	R							Yes
Zarma (NS) Tersis 1972	R	R							Yes

## 2.6.2 Languages allowing cluster NCs and final sonorant-stop clusters

This appendix contains a list of all surveyed languages in which NCs appear to pattern with clusters, each language annotated with information concerning its consonantal phonotactics. A key necessary to interpret the information about the consonantal phonotactics is provided in (64):

(64) Key for section 2.5.2

R	Restrictive (N–NC licensed prevocally only)
P	Permissive (N–NC licensed prevocally and word-finally)
-	No contrast in either position
(*)	No voicing contrast; phonetic implementation unclear

The list of surveyed languages, in Table 2.3, is below.

Table 2.3: List of surveyed NC segment languages

Basic information Language (Family) Source	Classification	Details	
	N–NC	D–ND	T–NT
Basque (Isolate) Hualde & de Urbina 2003	P	R	P
Breton (Indo-European) Press 1987	R	R	R
Catalan (Indo-European) Côté 2004	R	R	R
Dime (Afro-Asiatic) Seyoum 2008	P	P	P
Dutch (Indo-European) Kager & Zonneveld 1986	P	R	P
English, American (Indo-European) Kahn 1976	P	P	P
English, Trinidad (Indo-European) Katzir Cozier 2008	P	R	P
French, Québec (Indo-European) Côté 2000	P	R	P
German (Indo-European) Wiese 1996	P	P	P
Hungarian (Uralic) Grimes 2010	P	P	P
Hupa (Na-Dené) Woodward 1964	P	P	P
Iraqw (Afro-Asiatic) Mous 1993	P	R	P
Irish (Indo-European) O’Siadhail 1989	R	R	R
Jamul Tipay (Yiman) Miller 2001	P	–	P

Basic information	Classification	Details	
Language (Family) Source	N–NC	D–ND	T–NT
Lezgian (Northeast Caucasian) Haspelmath 1993	P	–	P
Livonian (Uralic) Moseley 2002	P	P	P
Ngan'gityemerri (Southern Daly) Reid 2011	R	R	R
Passamaquoddy (Algic) LeSourd 1988	P	(*)	(*)
Romanian (Indo-European) Chițoran 2002	P	P	P
Scots (Indo-European) Harris 1994	P	–	P
Totonac, Misantla (Totonacan) McKay 1991	P	(*)	(*)
Tübatulabal (Uto-Aztecan) Jensen 1973	P	R	P
Wardaman (Isolate) Merlan 1994	R	(*)	(*)
Yiddish (Indo-European) Jacobs 2005	P	P	P

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## Chapter 3

# Constraints on the Distribution of Allophonic Nasal-Stop Sequences

In this chapter, I broaden the claim that constraints on the distribution of nasal-stop sequences are constraints on contrast by arguing that constraints on the contrast between oral and nasal vowels are responsible for implicational generalizations in the typology of allophonic nasal-stop sequences. The observations about the phonology of allophonic nasal-stop sequences come from the typology of environmental shielding in South American languages (hereafter just *shielding*), a term used to refer to a class of processes in which the phonetic realization of a nasal stop depends on its local vocalic context. In Karitiâna (Tupí; Storto 1999), for example, where vocalic nasality is contrastive (e.g. [opi] ‘ear-ring’ vs. [opĩ] ‘to cut’, Storto p. 14), a nasal consonant acquires a brief oral phase at any position in which it is directly adjacent to an oral vowel. Examples are provided in (1) (though cf. Everett 2007 for a slightly different description).

(1) Shielding in Karitiâna (Storto 1999:25-26)<sup>1</sup>

- a. /m/ → [mb] /  $\tilde{V}_V, \#_V$   
ex. /ãmo/ → [ã**mb**o] ‘to climb’
- b. /m/ → [bm] /  $V_\#, V_\tilde{V}$   
ex. /kam/ → [ka**bm**] ‘now’
- c. /m/ → [bmb] /  $V_V$   
ex. /apimik/ → [api**bmb**ik] ‘to pierce’
- d. /m/ → [m] / *elsewhere*  
ex. /ãmãŋ/ → [ãmãŋ] ‘to plant’

To understand what motivates the alternations in (1), consider the alternative: if a pure nasal consonant were realized as such before an oral vowel, e.g. /ma/ → [ma], the oral vowel would likely carry some degree of perseveratory nasal coarticulation (see Everett 2007:140–142 on variation between shielding and vowel nasalization in Karitiâna). Since a major perceptual cue to the contrast between oral and nasal vowels is a difference in the duration of acoustic nasality (see Whalen & Beddor 1989), nasalization of an oral vowel in a given context presumably reduces the perceptibility of the contrast between it and a nasal vowel in that same context. Shielding, or raising of the velum prior to the onset of the oral vowel, prevents coarticulatory nasalization from occurring. The result is that, when shielding occurs, the contrast between oral and nasal vowels is rendered maximally distinct.

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<sup>1</sup>The exact allophones that shielding produces in Karitiâna are to some extent speaker-dependent. Older speakers produce an [mb] allophone in the  $\#_V$  environment, but younger speakers lose the nasalization word-initially and produce only [b]. See Storto 1999:20 for more information.

The hypothesis that shielding helps preserve contrasts in vocalic nasality is due to Herbert (1986) and has since been adopted by many others (e.g. Steriade 1993a:448, Ladefoged & Maddieson 1996:103–106, Flemming 2004:256–258, Wetzels 2008). In what follows, I formalize a contrast-based analysis of shielding in Dispersion Theory (Flemming 2002, 2008b), identify several of its predictions, and show that they are borne out. For example, if shielding is a strategy to preserve contrasts in vocalic nasality, shielding should only be attested in languages that license a contrast in vocalic nasality: if there is no contrast to protect, then there is no need to shield. In section 3.2, I present results of a large typological survey that verify this prediction. In addition, the contrast-based analysis predicts that if a language exhibits shielding in a context where the contrast between oral and nasal vowels is more distinct, it should exhibit shielding in all contexts where the contrast is less distinct. In section 3.3 I show that this prediction, too, is correct. Finally, in section 3.4, I show that the contrast-based analysis makes correct predictions not only about the typology of shielding, but also about the larger typology of vowel nasalization contrasts.

In section 3.5, I argue that not only is a contrast-based analysis a workable analysis of the shielding typology, but that *any* workable analysis of shielding must explicitly reference contrast. I discuss three potential alternatives: that shielding is the result of spreading [-nasal] (e.g. Storto 1999, Eberhard 2004), that the typology can be analyzed using perceptual CUE constraints (Escudero & Boersma 2003, Boersma 2009), and that shielding results not from any synchronic pressure but rather as a result of channel bias, or innocent misapprehension (e.g. Ohala 1981, Blevins 2004, Moreton 2008). Unlike the contrast-based analysis, all of these alternatives face problems in accounting for the generalizations presented here. Given the lack of a clear alternative, I conclude that environmental shielding is contrast preservation: alternations like (1) occur to preserve underlying contrasts in vocalic nasality. More broadly, contrast and the constraints that reference it are essential components of phonological theory.

Readers may wish to note at the outset that while the generalizations established here are based on a large number of languages (422 across all sections), this sample is not geographically balanced. The survey of 324 languages reported in section 3.1 is composed entirely of languages indigenous to South America; the smaller survey of 98 reported in section 3.4 is composed mainly of languages whose grammars are on the shelves at MIT’s Hayden Library and have call numbers ranging between PL5000–PM7875. The decision to restrict the survey in section 3.1 to South American languages was made due to a desire to conduct a large survey that includes as many languages with shielding as possible, as well as a suspicion, based on pre-existing literature, that South America is a place where such a sample could be obtained. The decision to restrict the survey in section 3.4 to the PL5000–PM7875 region of MIT’s Hayden Library was essentially arbitrary: surveying all grammars in the library would have taken an extraordinary amount of time, and the PL5000–PM7875 region houses the highest concentration of modern descriptive grammars in Hayden.

Narrowly, then, the conclusions drawn here hold only for the collection of languages that is under investigation in this study. While I expect that further work would support this study’s implicit prediction that all generalizations established here are universal, further work involving a more typologically diverse sample is necessary to verify this.

### 3.1 The typology of shielding

In this section, I address a basic prediction of a contrast-based approach to shielding: that shielding should occur only in languages that license a contrast in vocalic nasality. Section 3.1.1 presents the results of a large typological study suggesting that this prediction is correct, and discusses a couple

of apparent counterexamples. Section 3.1.2 lays out what the successful criteria for an analysis of the typology are, and formalizes an analysis in Dispersion Theory (Flemming 2002, 2008b).

### 3.1.1 Survey methodology and results

The contrast-based approach to shielding sketched above makes a basic typological prediction: if shielding occurs to protect a contrast in vocalic nasality, then we expect shielding to occur only in languages that license a contrast in vocalic nasality. In other words, while the Karitiâna pattern is predicted by a contrast-based analysis, we do not expect Karitiâna' (2) to exist. In this hypothetical system, nasals are realized as (partially) oral consonants when adjacent to oral vowels, even though there is no contrast in vocalic nasality.<sup>2</sup>

- (2) Karitiâna': shielding with no contrast in vocalic nasality
- a. /m/ → [mb] / #\_V    ex. /ma/ → [mba]    (but \*[mã], \*[pã])
  - b. /m/ → [bm] / V\_#    ex. /am/ → [abm]    (but \*[ãm], \*[ãp])
  - c. /m/ → [bmb] / V\_V    ex. /ama/ → [abmba]    (but \*[ãmã], \*[ãpã])

Herbert (1986:219), following Haudricourt (1970), claims that this prediction is correct: shielding processes "...are perceptually conditioned and never obtain in languages which do not oppose nasal and non-nasal vowels." To test the prediction more thoroughly, I surveyed languages in the South American Phonological Inventory Database (SAPhon), a database of phonemic inventories in South American languages. As of November 2016, when the survey was conducted, inventories and references for 363 languages (hailing from 76 different language families, including 36 isolates) were included in the database. Of these, I was able to locate at least one of the cited sources for 324 languages. These languages were divided into four groups, according to two parameters: whether or not they license a contrast in vocalic nasality, and whether or not they exhibit shielding. The criteria used to classify each language along both of these parameters are described below.

#### *Does a language license a contrast in vocalic nasality?*

Whether or not a language licenses a contrast in vocalic nasality was determined by consulting the phonemic inventory proposed in the grammars used as references as well as any additional discussion regarding the role of vocalic nasality in the language's phonology in those grammars. Of the 149 systems in which nasality was claimed to be lexically contrastive, in 81 I was able to verify this claim by locating minimal or near-minimal pairs. In 62, (near-)minimal pairs were not easy to find, but I was able to locate at least one example of a nasal vowel transcribed in a non-nasal consonantal environment (e.g. forms like [kã]). In the remaining six systems, additional evidence of this sort was difficult to find, due to a lack of data provided in the description. In the appendix A to this chapter (section 3.6), each language claimed to exhibit a contrast in vocalic nasality is annotated with the type of additional evidence that supports the claim, where such additional evidence is available.

#### *Does a language exhibit shielding?*

Whether or not a language exhibits shielding was determined by examining the allophonic realizations of its nasal consonants. A language 'has shielding' if its nasal consonants (e.g. [n]) appear as

<sup>2</sup>Languages that lack nasal consonants and vowels, e.g. Pawnee (Parks 1976), could be treated as cases where shielding obligatorily applies in all contexts (/m/ → [b] before oral vowels; since all vowels are oral, [m] never surfaces). But without evidence that all surface oral stops are derived from underlying nasals, it is simpler to state that these languages lack nasals. Evidence that shielding exists in a language without a contrast in vocalic nasality could come from (i) variability in the output, e.g. shielding only sometimes applies; (ii) a contextual restriction on shielding (see Chapter 3.2.2), or (iii) the preservation of [+nasal] in some or all allophones that the shielding process produces (as in (2)).

oral (e.g. [d]) or partially oral (e.g. [nd]) voiced stops when directly adjacent to an oral vowel. In the minority of cases where spectrograms were available, I used these to confirm the author's description – the spectrograms for Krenak nasals (Pessoa 2012:92–97), for example, are consistent with the presence of shielding; the provided spectrograms for Shipibo nasals (Elías-Ulloa 2010:160–165) are consistent with its absence.

A note is necessary here regarding the relationship between [+nasal] spreading and shielding. In a language that licenses a contrast in vocalic nasality (so [ta] and [tã]), and exhibits complementary distribution between nasal and oral stop allophones according to the nasal vs. oral quality of the surrounding vowels (so [mã] and [ba], but \*[ma] and \*[bã]), there are in principle two possible analyses of this distribution. The first possibility is that the nasal stop is an allophone of the oral stop, arising due to the influence of a following [+nasal] vowel (so /b/ → [m] / \_[+nasal]). The second possibility is that the oral stop is an allophone of the nasal stop, arising due to the influence of a following [-nasal] vowel (so /m/ → [b] / \_[-nasal]). The interest of this chapter is in cases of the latter variety, where nasal stops require a period of orality when adjacent to oral vowels. But in languages where the nasal and oral allophones are in strict complementary distribution, it can be impossible to determine which of the above analyses is correct – a fact that is explicitly noted by some authors (see e.g. Cathcart 1979:11 on this difficulty of analysis in Kakua).

In this survey I have taken an inclusive approach towards what counts as 'shielding', so as to provide as many chances as possible for the contrast-based hypothesis to be falsified. I have counted a language as 'having shielding', or exhibiting variation between a nasal phoneme and its oral allophone conditioned by a neighboring vowel, in all cases where this is a plausible interpretation of the data.<sup>3</sup> Thus languages like Kakua, for which it is impossible to determine whether the alternations are due to shielding or to nasal harmony, are counted as 'having shielding'. By contrast, cases in which it is more likely that the complementary distribution is due to a process of [+nasal] harmony – as is clear for Pisamira (Tucanoan, de Pérez 2000), for example, where long-distance [+nasal] harmony is independently attested – are not counted as 'having shielding'. All 'shielding' languages for which there is a question of analysis are annotated as such in section 3.6.2.

It is important to note that even if the use of these criteria has caused me to misclassify a language as 'having shielding' when it does not, or vice versa, this does not impact in any way the generalizations drawn here. The prediction under investigation in this section is that *if a language displays shielding, it must license a contrast in vocalic nasality*. By definition, all languages for which there is a question of analysis license a contrast in vocalic nasality; the theory does not predict, one way or the other, whether or not they should exhibit shielding.

## Survey results

The survey result is presented in (3). With three potential exceptions, all languages that display shielding license a contrast in vocalic nasality (a V- $\tilde{V}$  contrast). For more information on each of the 66 languages that exhibits shielding and a contrast in vocalic nasality, see section 3.6.1 (a list of shielding languages, with some basic information) and section 3.6.2 (more detailed information on each of the 66 languages). For a list of the remaining 255 languages that do not exhibit shielding, see section 3.6.3.

<sup>3</sup>I do not consider cases where the allophonic variation is very clearly due to the influence of a neighboring consonant: in Palikúr (Launey 2003), for example, stem-final stops are realized as nasal when a nasal-initial suffix is added.



		Shielding	No shielding
(3)	No V- $\tilde{V}$ contrast	<b>3 lgs.</b> e.g. Umotína (Schultz 1952)	<b>172 lgs.</b> e.g. Shipibo (Elías-Ulloa 2010)
	V- $\tilde{V}$ contrast	<b>66 lgs.</b> e.g. Karitiâna (Storto 1999)	<b>83 lgs.</b> e.g. Urarina (Olawsky 2006)

As is clear from (3), the prediction of the contrast-based approach is largely borne out: the vast majority of ‘shielding’ languages license a V- $\tilde{V}$  contrast. In the following subsections I suggest that the three apparent counterexamples – attested in Umotína (Macro-Ge; Lima 1995) and two dialects of Ese Ejja (Tacanan; Chavarria 2012, Vuillermet 2012) – are only apparent, and from this point forward I do not consider them to be languages that exhibit shielding. For discussion of other possible counterexamples that fall outside of the range of languages surveyed here, see section 3.5.2.

### Shielding in Umotína

Umotína, which does not license a contrast in vocalic nasality, exhibits variation between [m] and [b] in the form [iremo’to] ~ [irebo’to] ‘I find’ (translation mine). Lima (1995:43) writes that “although the fluctuation is extremely restricted and [b] is widely represented in the corpus, [she] decided to consider [b] an allophone of /m/” (translation mine). Lima notes that this analysis lines up with the observations of Schultz (1952:86), who writes that “all of the ‘m’s and ‘b’s vary between a definitive pronunciation of ‘m’ and ‘b’, depending on the speaker in question” (translation mine).<sup>4</sup>

Further discussion (Lima p. 43) reveals that it may be possible to predict the distribution of [m] and [b] in Umotína by appealing to the syllabicity of the following segment: [b] appears before [-syllabic] /w/ and /j/, and [m] appears before all [+syllabic] vowels. If Lima’s analysis of the distribution of [m] and [b] is correct, then there is an analysis available under which the language does not exhibit shielding but rather variation conditioned by syllabic position. Under this analysis, the contrast between [m] and [b] is neutralized in all positions, with [m] as the default allomorph that appears before vowels (perhaps to maximize the contrast between it and the only other labial stop – the voiceless /p/). In consonant-glide clusters, however, /m/ is realized as [b], perhaps in order to maximize the cluster-internal sonority rise (see Zec 2007:188–189 for an overview of minimal sonority distance in clusters).

### Shielding in Ese Ejja

The remaining two systems that exhibit shielding despite not allowing a contrast in vocalic nasality are both dialects of Ese Ejja (or Ese Eja; Tacanan). Chavarria’s (2012) description of Peruvian Ese Ejja notes that, for speakers of the Palma Real dialect, “the phonemes /m/ and /n/ [...] are realized as [b] and [d], but lightly nasalized” (translation mine) – thus the form /nono/ (‘brother’, translation mine) can for these speakers be realized as [nono] or [dōdō] (Chavarria p. 23).

Vuillermet’s (2012) description of shielding in Bolivian Ese Ejja is similar – the bilabial and alveolar nasal consonants vary allophonically with oral consonants at the same place of articulation, as illustrated in (4) (data from Vuillermet 2012:169). Vuillermet notes that the variation is conditioned by speech register: nasal allophones are more common in hyperarticulated speech, while oral allophones are more common in fast speech.<sup>5</sup>

<sup>4</sup>Schultz (1952) transcribes [b]s and [m]s in his lexicon, but does not discuss how these sounds were distinguished.

<sup>5</sup>There is also a rare palatal nasal in Ese Ejja that varies very rarely with [j]. In most cases it appears in loanwords or as a result of a diachronic palatalization process that occurred in the environment i\_{o,a} (see Vuillermet 2012:169).

- (4) Shielding-like behavior in Bolivian Ese Ejja
- |    |                 |   |                     |
|----|-----------------|---|---------------------|
| a. | <b>miya</b>     | [ <b>m</b> iya] ~ [ <b>b</b> iya]         | ‘2SG.ABS’           |
| b. | <b>mei</b>      | [ <b>m</b> bej]                           | ‘stone’             |
| b. | <b>xemi</b>     | [ <b>x</b> emi] ~ [ <b>x</b> ebi]         | ‘squash sp.’ (joco) |
| c. | <b>naba’ewi</b> | [ <b>na</b> ʃa’ewi] ~ [ <b>da</b> ʃa’ewi] | ‘fish sp.’ (bentón) |

Given the available data, there is an alternative analysis: [n] and [m] are not underlying phonemes, but rather allophones of oral /(n)d/ and /(m)b/. The /(n)d/ → [n] and /(m)b/ → [m] alternations occur in order to maximize cues to the contrast between the non-laryngealized stop series (e.g. /b/) and a co-existing laryngealized series (e.g. /b̥/; see Vuillermet 2012 on voicing in implosives): a [m-ɓ] contrast is presumably more distinct than a [b-ɓ] contrast, as [ɓ] is acoustically more similar to [b] than it is to [m]. The hypothesis then is that the attested alternations in Ese Ejja are also a form of contrast enhancement, albeit one motivated by different factors than those that motivate shielding.

### Local summary

The survey presented in this subsection shows that if shielding exists in a given language, so must a contrast in vocalic nasality.

I consider briefly whether or not the finding discussed in this subsection could be an artifact of descriptive bias: if a linguist were to encounter a language that exhibits shielding, but no contrast depends on it, would the linguist be likely to make note of the fact that shielding exists? While it is impossible to rule out this situation – very few of the references provide acoustic measurements, meaning that in the vast majority of cases, the reader must blindly trust the author’s description – it seems at odds with the fact that many of the descriptions referenced in SAPHon do discuss non-contrastive details about the realization of nasality. For example, in a number of descriptions, the authors provide a somewhat detailed description of allophonic nasalization, conditioned by nasal consonants in certain contexts (see e.g. Zariquiey 2011 on Cashibo-Cacataibo, Pachêco 2001 on Ikpeng, dos Anjos 2011 on Katukina, Chapman & Derbyshire 1991 on Paumarí, Couto 2010 on Saynawa, and Elías-Ulloa 2010 on Shipibo, among others).

Vocalic nasality is not contrastive in any of the languages cited above, yet the authors make a point to transcribe allophonic nasalization of vowels anyway. Thus in order to maintain the claim that the asymmetry in (3) is an artifact of descriptive bias, there would have to be a good reason why a linguist would be more likely to overlook the existence of shielding than they would be to overlook the existence of allophonic nasalization. Especially given that the vast majority of these descriptions are authored by linguists who natively speak a language with allophonic nasalization and not shielding – most if not all cited sources appear to be written by native speakers of English, French, Portuguese, or Spanish – I find this situation unlikely. One would naïvely expect that, when describing a language, a linguist would be more likely to notice (and transcribe) those features of the target language that differ from those of their native language.

### 3.1.2 Analysis

Having presented the survey results, we can now outline several desiderata for a successful analysis of shielding. First, the analysis of shielding must be able to reference facts about a language’s phonemic inventory: in order to correctly predict that shielding should only occur in languages that license a contrast in vocalic nasality, whatever motivates shielding must be sensitive to the structure of a language’s vowel inventory in some way. Second, phonology must be able to ‘see’ the output of the phonetic grammar (an argument familiar from Jun 1995, Steriade 1997, *a.o.*). Presumably,

the duration and extent of coarticulatory nasality is controlled by a language's phonetic grammar. For shielding to be motivated, the phonological grammar must be aware that oral vowels in nasal environments are nasalized, and as a result become less distinct from nasal vowels.

These desiderata exclude an analysis of the typology under which shielding is motivated by constraints of the form \*NV and \*VN (a nasal consonant must not be adjacent to an oral vowel), for the simple reason that constraints like \*NV and \*VN are not sensitive to the structure of a language's larger vocalic inventory. A claim that \*NV or \*VN resides in CON entails the prediction, by factorial typology, that shielding could possibly occur in any language – regardless of whether or not it licenses a contrast in vocalic nasality. (If \*NV is undominated, and faithfulness to nasalization in vowels is prized over faithfulness to nasalization in consonants, then shielding will result regardless of the presence vs. absence of a contrast in vocalic nasality. Since the survey results show that this prediction is incorrect, then \*NV and \*VN are not the right constraints to motivate shielding, and likely do not belong in CON.<sup>6</sup> Instead, a successful analysis of the typology of shielding requires constraints that explicitly reference contrast; without these, the analysis cannot make the right predictions.<sup>7</sup>

Both of the desiderata outlined above can be easily satisfied by assuming the architecture of the phonological grammar outlined by Flemming (2008b). As discussed in Chapter 1, Flemming (2008b) assumes that the phonological grammar is composed of multiple sequenced components: we will focus here on the phonotactic component of the grammar, which evaluates a input representation that is fully phonetically specified, the Realized Input (see Chapter 1 for an overview of the full model). Because the input material is fully phonetically specified, phonotactic constraints are therefore able to make reference to predictable phonetic information. The analyses proposed here will appeal to three types of constraints: distinctiveness constraints (i.e. MINDIST), which set thresholds of contrast distinctiveness; other markedness constraints, penalizing particular output configurations (e.g. \*CONTOUR); and faithfulness constraints, here constraints on Input-Output (IO) mappings (e.g. MAX[+nasal]). To show how these three types of constraints work together to derive shielding, I develop an analysis of the Karitiâna pattern; the data originally provided in (1) are repeated as (5) below.

(5) Shielding in Karitiâna (Storto 1999:25-26)

- a. /m/ → [mb] /  $\tilde{V}$ \_V, #\_V  
ex. /ãmo/ → [ã**mb**o] 'to climb'
- b. /m/ → [bm] / V\_#, V\_ $\tilde{V}$   
ex. /kam/ → [ka**bm**] 'now'
- c. /m/ → [bmb] / V\_V  
ex. /apimik/ → [api**bmb**ik] 'to pierce'
- d. /m/ → [m] / *elsewhere*  
ex. /ãmãŋ/ → [ãmãŋ] 'to plant'

Throughout the data in (5), there is a clear preference for nasal consonants in the input to remain at least partially so in the output. This preference is especially apparent in (5c), where the presence

<sup>6</sup>While \*NV could be used to motivate nasal coarticulation, there are alternatives: one is that the constraints encouraging coarticulation either reward long velic gestures or penalize short ones.

<sup>7</sup>The analysis involving constraints like \*NV and \*VN could potentially be saved if we assume that [ $\pm$ nasal] is only specified when a V- $\tilde{V}$  contrast is present. To the extent that this proposal is successful, it underscores one major argument of this chapter: that any successful analysis of shielding must in some way explicitly reference contrast. The proposal is however incapable of accounting for the further generalizations regarding positional asymmetries in section 3.2; see section 3.4.1 for additional related discussion.

of oral vowels on both sides of a nasal consonant yields [bmb]. This drive to preserve the [+nasal] value of an underlyingly nasal consonant can be formalized as MAX[+nasal] (6).

- (6) MAX[+nasal]: assign one violation for each [+nasal] feature present in the input that is absent in the output.

It is also the case that there is a clear preference for input oral vowels to remain as such in the output; oral vowels are never nasalized. This drive to preserve the [-nasal] value of an underlyingly oral vowel can be formalized as MAX[-nasal] (7).<sup>8</sup>

- (7) MAX[-nasal]: assign one violation for each [-nasal] feature present in the input that is absent in the output.

To explain why shielding does not occur in some languages, or induces alternations between fully nasal and fully oral stops (in Jabutí for example, /m/ → [b] / \_V; Ribeiro & van der Voort 2010), we need a constraint that bans nasal contours. For this chapter, \*CONTOUR – penalizing consonants linked to both [+nasal] and [-nasal] (8) – is sufficient. Concretely, I assume that postoralized consonants (e.g. [mb]) are linked sequentially to [+nasal] and [-nasal]; pre-oralized consonants (e.g. [bm]) to [-nasal] and [+nasal], and medionasals (e.g. [bmb]) to [+nasal], [-nasal], and [+nasal]. (On representing nasal contours, see e.g. Anderson 1976, Steriade 1993a.) Presumably, \*CONTOUR is a constraint on articulatory effort: nasal contours involve not only velum lowering, velum raising, oral opening, and oral closing gestures, but also precise coordination among them.

- (8) \*CONTOUR: assign one violation for each output consonant linked to [+nasal] and [-nasal].

Finally, we need a MINDIST constraint to motivate shielding. MINDIST constraints are markedness constraints that set thresholds of distinctiveness for a given contrast, and assign violations to contrasts that are insufficiently distinct. For example, we might imagine that in Karitiãna there is a MINDIST constraint requiring oral and nasal vowels to be maximally different. In this situation, an oral vowel must be fully oral and nasal vowel must be fully nasal in order for the contrast between them to be sufficiently distinct. This MINDIST constraint is formalized as NASDUR in (9).

- (9) MINDIST V– $\tilde{V}$  (NASDUR): for a contrast in vocalic nasality to be sufficiently distinct, the oral vowel must be fully oral and the nasal vowel must be fully nasal. Assign one violation for each violating pair.

A contrast that satisfies NASDUR is the fully oral vowel in [mba] (10a) versus the fully nasal vowel in [mã] (10c): because the oral vowel is fully oral and the nasal vowel is fully nasal, the contrast between them is sufficiently distinct. A pair that violates NASDUR is the nasalized oral vowel in [m<sup>a</sup>a] (10b) versus the fully nasal vowel in [mã] (10c): because the oral vowel is marked by some extent of acoustic nasality, the contrast between it and a nasal vowel is not sufficiently distinct. (Throughout, the presence of coarticulatory nasalization is denoted with a superscripted nasal vowel.)

- (10) Comparisons between oral and nasal vowels

- a. Fully oral vowel:

mb	a
----	---

<sup>8</sup>Alternatively, the faithfulness constraints could militate against changing the [±nasal] values of consonants (IDENT[±nasal]-CONS) and vowels (IDENT[±nasal]-VOWEL). Shielding would result when maintaining the [±nasal] specification of the vowel is more important than maintaining the [±nasal] specification of the consonant (so IDENT[±nasal]-V ≫ IDENT[±nasal]-C). For present purposes, the two analyses are equivalent.

- b. Nasalized oral vowel:

m	<span style="background-color: #cccccc;">ã</span>	a
---	---	---

- c. Fully nasal vowel:

m	<span style="background-color: #cccccc;">ã</span>
---	---

The tableau in (11) assumes that the Realized Inputs of /ma/ and /mã/ are /m<sup>ã</sup>a/ and /mã/, respectively. To be concrete, I assume that nasal coarticulation occurs in the Phonetic Realization component of the grammar. I leave aside questions of how the constraints that promote it are defined and how they interact with others, as these questions are orthogonal and are not directly relevant to the issues at hand – our focus is not on how nasal coarticulation arises, but on how the phonotactic grammar responds to it.

Whether or not NASDUR motivates modification of the /m<sup>ã</sup>a–mã/ contrast, and what form this modification takes, depends on the ranking of NASDUR with respect to the other constraints defined above. For expository purposes, I assume here that mapping the realized input /m<sup>ã</sup>a/ to output [ma], with no perseveratory nasal coarticulation, would fatally violate articulatory constraints that disprefer precise synchronization of the velum and tongue/lip gestures. Output candidates in which an oral vowel adjacent to a nasal consonant remains fully oral will not be considered here or elsewhere (though see the end of this subsection on phonetic variation).<sup>9</sup>

- (11) Possible responses to an indistinct contrast in vocalic nasality

m <sup>ã</sup> a mã	NASDUR	*CONTOUR	MAX[+nasal]	MAX[-nasal]
a. m <sup>ã</sup> a mã	*			
b. mba mã		*		
c. ba mã			*	
d. mã mã				*

The faithful candidate (11a) is dispreferred by NASDUR: the oral vowel contains some degree of acoustic nasality, and is therefore not fully distinct from a nasal vowel. Note that partially nasalized vowels, as in (11a), do not violate \*CONTOUR: as defined in (8), \*CONTOUR only penalizes nasal contour consonants. The fact that consonantal contours are penalized but vocalic contours are not is consistent with the typological observation that few languages allow nasal consonant contours but many allow partially nasalized vowels. This can likely be traced to a difference in the amount of articulatory effort involved: partially nasalized vowels, unlike partially nasalized consonants, do not require precise coordination among velum lowering/closing and oral opening/closing gestures.

Candidate (11b), where shielding results in a contour segment, violates \*CONTOUR. Candidate (11c), where shielding results in a fully oral consonant, is dispreferred by MAX[+nasal]: the fully oral consonant corresponds to an input consonant linked to [+nasal]. And finally, candidate (11d), where the contrast in vocalic nasality is neutralized, incurs a violation of MAX[-nasal]. Different rankings of constraints predict different outcomes; in the particular case of Karitiâna, where shielding results in nasal contours, \*CONTOUR must be demoted to derive the correct result (12).<sup>10</sup>

<sup>9</sup>I also do not consider candidates where shielding applies but the adjacent vowel is nasalized, e.g. [mb<sup>ã</sup>a–mã] or [b<sup>ã</sup>a–mã], as these candidates are harmonically bounded: they both violate NASDUR and one other constraint in (11).

<sup>10</sup>For younger Karitiâna speakers, recall that /m/ → [b] / #\_V. To derive the fact that avoidance of contour segments takes priority for these speakers, \*CONTOUR ≫ MAX[-nasal]. The appearance of contours in the  $\tilde{V}_V$  context would then have to be attributed to an additional constraint that bans nasal vowels from preceding fully oral consonants (\*VC).

(12) Demoting \*CONTOUR derives Karitiâna shielding

	m <sup>ã</sup> a m <sup>ã</sup>	NASDUR	MAX[+nasal]	MAX[-nasal]	*CONTOUR
a.	m <sup>ã</sup> a m <sup>ã</sup>	*!			
b.	mba m <sup>ã</sup>				*
c.	ba m <sup>ã</sup>		*!		
d.	m <sup>ã</sup> m <sup>ã</sup>			*!	

Note that for speakers of languages that lack a contrast in vocalic nasality, NASDUR is irrelevant. Because the constraint can only be evaluated in environments where oral and nasal vowels contrast, nasalization of oral vowels in systems where there are no contrasting nasal vowels does not violate NASDUR. As shown in the tableau in (13), modification of NV sequences in languages *without* a contrast in vocalic nasality is not motivated by NASDUR, and therefore blocked by other markedness and faithfulness constraints that disprefer the result. It is impossible, then, to generate a system in which shielding occurs in the absence of a contrast in vocalic nasality. This is a desirable result, as such systems are unattested.<sup>11</sup>

(13)

	m <sup>ã</sup> a	NASDUR <sub>100%</sub>	*CONTOUR	MAX[+nasal]	MAX[-nasal]
a.	m <sup>ã</sup> a				
b.	mba		*!		
c.	ba			*!	
d.	m <sup>ã</sup>				*!

Up to this point, I have assumed that oral vowels adjacent to nasal consonants are nasalized to some degree. While the phonetics of coarticulatory nasalization do vary by language (e.g. Cohn 1990), there are regularities. In most of the world's languages, oral vowels adjacent to nasal consonants are reported to be nasalized to some degree (though cf. Chan & Ren 1987 on Miao, and Butcher 1999 on a number of Australian languages). By contrast, oralization of nasal vowels adjacent to oral consonants is rarely described, and in the one case I'm aware of (French, Cohn 1990), oralization is brief. Given these facts, for this chapter I make two simplifying assumptions: (1) oral vowels adjacent to nasal consonants are always nasalized, and (2) nasal vowels adjacent to oral consonants are fully nasal. While a full version of the overall theory would build language-specific variation into the analysis, this is not currently feasible, as we do not know what the range of variation is. It is important to note, however, that incorporating language-specific phonetic detail into the analysis would not change in any way the overall predicted typology. In languages where coarticulatory nasalization is completely absent, for example, shielding would just not be motivated.

## 3.2 Asymmetries in the typology

Looking beyond Karitiâna, we find that languages differ in unpredictable ways as to the sets of allophones that shielding can license. The only generalization apparent in (14) is that if a language licenses medionasals (e.g. [bmb]), it also licenses other contours.

<sup>11</sup>A question arises here: in a language with shielding, how does the learner know that a contrast in vocalic nasality would have been in danger, had shielding not occurred? The hope is that learners are able to infer what the non-shielding outcome would have been, based on variability in the outcome. In 29 of the 69 descriptions consulted, the author reports that shielding does not always apply (see section 3.6.2). There is of course the possibility that variability in the output might not provide enough evidence to the learner, as the extent of coarticulatory nasalization can vary both across and within speakers; it could also be the case that the learner is able to extrapolate the potential patterns of nasal coarticulation based on other kinds of coarticulation in the language, though this is pure speculation.

(14) Attested sets of (partially) nasal allophones licensed in shielding languages

[b]	[mb]	[bm]	[bmb]	Example (Source)
✓				Kakua (Cathcart 1979)
✓	✓			Epena (Harms 1984)
✓		✓		Yuhup (Martins 2005)
✓	✓	✓		Arara (da Rocha D'Angelis 2010)
	✓			Tenharim (Sampaio 1998)
		✓		Nadëb (Barbosa 2005)
	✓	✓		Amundava (Sampaio 1998)
	✓	✓	✓	Kaingáng (Cavalcante 1987)

There are, however, predictable asymmetries in the typology of shielding that mirror cross-linguistic asymmetries in the direction and extent of nasal coarticulation. Section 3.2.1 presents a survey on the phonetics of nasal coarticulation (drawing mainly from Diakoumakou 2004 and Jeong 2012), and section 3.2.2 shows that asymmetries in the typology of shielding are correctly predicted by the phonetic asymmetries. The major generalization that emerges in this section is the following: if a language licenses shielding in a context where we expect contrasts in vocalic nasality to be relatively distinct, then it will also license shielding in all contexts where we expect contrasts in vocalic nasality to be less distinct. Section 3.2.3 shows that this cross-linguistic generalization is predicted by a contrast-based analysis, and section 3.2.4 suggests that the generalization also holds within the grammars of individual languages.

### 3.2.1 The phonetics of nasal coarticulation

It is well-known that languages display asymmetries in the direction and extent of nasal coarticulation. In Table 3.1, I have summarized data from a variety of phonetic studies that illustrate the known asymmetries. The discussion here focuses on three contexts where coarticulation occurs: perseveratory (NV), tautosyllabic anticipatory ( $VN]_{\sigma}$ ), and heterosyllabic anticipatory ( $V]_{\sigma}N$ ). To the best of my knowledge, further contextual asymmetries (i.e. between word-initial perseveratory, #NV, and word-medial perseveratory, VNV) have not been discussed in the literature. This survey draws mostly on pre-existing work by Diakoumakou (2004) and Jeong (2012), though I have verified all facts with the original sources wherever possible. The cases below include only those languages where there is a claimed asymmetry. Languages like Bengali, where anticipatory and perseveratory coarticulation are claimed to be equal (Diakoumakou 2004:145), are not included.

For contexts in Table 3.1 where no data is available, the cell is blank. For contexts where data is available, the notation used depends on the source. If the source provides percentages (i.e. how much of an oral vowel is nasalized in a given nasal context), those percentages were recorded. In cases where the source provided multiple percentages for a given context, I have provided only the overall average.<sup>12</sup> When exact percentages were not provided, I did not try to measure them; instead, I used plus/minus notation. For each language, contexts where there is a plus (+) exhibit more nasalization than contexts where there is a minus (-); if two minuses are listed for a given language, it is not clear which context exhibits less nasalization. As what is important to this argument is only the asymmetries among the contexts considered below, the plus/minus notation is sufficient.

Several generalizations characterize the data in Table 3.1. First, perseveratory coarticulation (NV) is more extensive than heterosyllabic anticipatory coarticulation ( $V]_{\sigma}N$ ). The sole apparent

<sup>12</sup>For example: Huffman (1988) provides separate percentages for the two Akan tokens measured, and Flege (1988) provides separate percentages for different age groups. In these cases and others, to provide one value, I took the mean.

Table 3.1: Results of coarticulatory nasalization survey

Type	Language	NV	VN] <sub>σ</sub>	V] <sub>σ</sub> N	Source
1	Hindi	-	+		Ohala (1975:323)
	St. Lucian Creole	-	+	-	Bhatt & Nikiema (2000)
	Agwagwune	100%		15%	Huffman (1988)
	Akan	74%		92%	Huffman (1988)
	Arabic (Cairene)	72%	38%		Jeong (2012:450)
	Chinese (Standard)		+	-	Chen (2000)
	English (American) <sup>13</sup>	82%	76%		Flege (1988:532); see also Cohn (1990:143–147)
2	French	73%	33%	17%	Cohn (1990), Diakoumakou (2004:134)
	Greek	71%	57%	29%	Diakoumakou (2004)
	Ikalanga	75%		33%	Beddor & Onsuwan (2003)
	Italian	+	-	-	Farnetani (1986), via Diakoumakou (2004:136)
	Japanese (Standard)		+	-	Ushijima & Sawashima (1972:34)
	Swedish	+	-		Clumeck (1975)

exception to this generalization is Akan; in the cited study (Huffman 1988), however, the durations of anticipatory and perseveratory nasalization were roughly equivalent. Because the stimuli were of the form  $V_1NV_2$ , however, and  $V_2$  in these tokens is longer than  $V_1$ ,  $V_1$  was comparatively more nasalized than  $V_2$ . Further work is needed to see if the asymmetry found in Huffman’s (1988) study is in fact due to a difference in the amount of anticipatory vs. perseveratory nasalization, or rather to a durational asymmetry between word-final vowels and vowels in other positions.

The second generalization emerging from Table 3.1 is that tautosyllabic anticipatory coarticulation ( $VN]_{\sigma}$ ) is more extensive than heterosyllabic anticipatory coarticulation ( $V]_{\sigma}N$ ). While only four languages in Table 3.1 demonstrate this (Chinese, French, Greek, and Japanese), the tautosyllabic vs. heterosyllabic asymmetry has been documented more widely. In American English, for example, vowels are more nasalized before coda nasals than they are before onset nasals (Krakow 1993). Herbert (1977) discusses a large number of languages in which vowels are more nasalized before coda than before onset nasals, including Pashto, Malagasy, Delaware, Georgian, and Gypsy-Telugu. And on the basis of a large typological study of vowel nasalization, Schourup (1973:191) concludes that “... in no language examined are vowels nasalized before pre-vocalic [onset] nasals when they are not also nasalized before all preconsonantal and word-final [coda] nasals.”<sup>14</sup>

These two generalizations appear to hold for all languages: languages displaying the reverse asymmetries have not, to the best of my knowledge, been documented. But whether perseveratory (NV) coarticulation is more extensive than tautosyllabic anticipatory ( $VN]_{\sigma}$ ) coarticulation, or vice

<sup>14</sup>It isn’t crucial that the difference between the two classes of nasals is one of syllable position (onset vs. coda); I expect that differentiating nasals by their vocalic context (i.e. prevocalic vs. non-prevocalic) would work just as well. I use syllable-based notation here because this is the notation used in the majority of studies on nasal coarticulation.

<sup>14</sup>The status of American English as Type 2 is open to debate; Chen et al. (2007) suggest that, for at least some speakers, the amount of nasalization in  $VN]_{\sigma}$  is greater than the amount of nasalization in NV, and Cohn (1990) shows that vowels are more nasalized in some  $VN]_{\sigma}$  contexts (i.e. before voiceless nasal-stop clusters; see p. 175) than others.

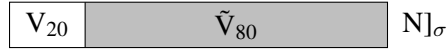


versa, depends on the language. In *Type 1* systems (labeled as ‘1’ in Table 3.1), tautosyllabic anticipatory coarticulation is more extensive than perseveratory coarticulation. In *Type 2* systems (labeled as ‘2’ in Table 3.1), either perseveratory coarticulation is more extensive than tautosyllabic anticipatory coarticulation, or the data necessary to determine this are not available.

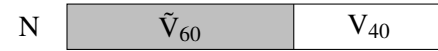
Given these generalizations, we expect systems that display asymmetries in nasal coarticulation to be of two types. In *Type 1* systems, the amount of nasal coarticulation in the tautosyllabic anticipatory context ( $VN]_{\sigma}$ ) is greater than the amount in the perseveratory context ( $NV$ ), which is greater than the amount in the heterosyllabic anticipatory context ( $V]_{\sigma}N$ ). Note that in these diagrams and all that follow, I assume that a vowel has some number of durational units  $n$ , which can be subdivided into nasal units and oral units. The precise subdivision between oral and nasal units is for illustrative purposes only. What matters here is only the asymmetries among the different contexts, not the exact amount of nasalization found in each of them.

(15) Type 1 systems:  $VN]_{\sigma} > NV > V]_{\sigma}N$

a. Tautosyllabic anticipatory coarticulation ( $VN]_{\sigma}$ )



b. Perseveratory coarticulation ( $NV$ )



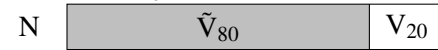
c. Heterosyllabic anticipatory coarticulation ( $V]_{\sigma}N$ )



In *Type 2* systems, the amount of nasal coarticulation in the perseveratory context ( $NV$ ) is greater than the amount in the tautosyllabic anticipatory context ( $VN]_{\sigma}$ ), which is greater than the amount in the heterosyllabic anticipatory context ( $V]_{\sigma}N$ ) (16).

(16) Type 2 systems:  $NV > VN]_{\sigma} > V]_{\sigma}N$

a. Perseveratory coarticulation ( $NV$ )



b. Tautosyllabic anticipatory coarticulation ( $VN]_{\sigma}$ )



c. Heterosyllabic anticipatory coarticulation ( $V]_{\sigma}N$ )



Assuming that the greater the duration of nasal coarticulation on an oral vowel, the less distinct it is from a nasal vowel, we can translate the phonetic asymmetries in (15–16) into predictions about where contrasts in vocalic nasality will be more and less distinct. In all systems, we expect contrasts in vocalic nasality to be more distinct in the heterosyllabic anticipatory context than in either the perseveratory or tautosyllabic anticipatory contexts, as oral vowels are less nasalized in the heterosyllabic anticipatory context (so  $\Delta V]_{\sigma}N - \tilde{V}]_{\sigma}N > \Delta NV - N\tilde{V}$ ,  $\Delta VN]_{\sigma} - \tilde{V}N]_{\sigma}$ ).<sup>15</sup> In *Type 1* systems, we expect contrasts in vocalic nasality to be more distinct in the perseveratory context than in the tautosyllabic anticipatory context ( $\Delta NV - N\tilde{V} > \Delta VN]_{\sigma} - \tilde{V}N]_{\sigma}$ ); in *Type 2* systems, we expect these contrasts to be more distinct in the tautosyllabic anticipatory context than they are in the perseveratory context ( $\Delta VN]_{\sigma} - \tilde{V}N]_{\sigma} > \Delta NV - N\tilde{V}$ ). See (17) for a summary.

<sup>15</sup>Here,  $\Delta x-y$  = ‘the perceptual distance between  $x$  and  $y$ .’

- (17) Expected distinctiveness of vocalic nasality contrasts
- Type 1 systems:  $\Delta V]_{\sigma}N-\tilde{V}]_{\sigma}N > \Delta NV-N\tilde{V} > \Delta VN]_{\sigma}-\tilde{V}N]_{\sigma}$
  - Type 2 systems:  $\Delta V]_{\sigma}N-\tilde{V}]_{\sigma}N > \Delta VN]_{\sigma}-\tilde{V}N]_{\sigma} > \Delta NV-N\tilde{V}$

If shielding is a strategy to maximize cues to contrasts in vocalic nasality, then we would expect the phonetic asymmetries outlined above to yield an implicational generalization regarding the contexts in which shielding occurs. The prediction is as follows: if a given language licenses shielding in a context where a contrast in vocalic nasality is *more* distinct, then it must license shielding in all contexts where the contrast is *less* distinct. For example, in both Type 1 and Type 2 systems, shielding in the heterosyllabic anticipatory context ( $V]_{\sigma}N$ ) should imply shielding in both the perseveratory (NV) and tautosyllabic anticipatory ( $VN]_{\sigma}$ ) contexts, because we expect contrasts in vocalic nasality to be more distinct in the heterosyllabic anticipatory context than they are in either the perseveratory or tautosyllabic anticipatory contexts. What we do not expect to find are systems in which shielding applies in limited contexts, to preserve only the more distinct contrasts in vocalic nasality (e.g. in the heterosyllabic anticipatory context only).

### 3.2.2 Testing the predictions

Taking into account the predicted typological asymmetries outlined above, a full list of the predicted and non-predicted shielding patterns is provided in (18). A check mark indicates the presence of shielding in the relevant context; the absence of a checkmark means there is no shielding. Note that while the predictions in (18) are predictions about the typology of shielding, the asymmetries in the phonetics of nasal coarticulation that generate these predictions are based on a set of languages that do not license shielding. The linking assumption is that the phonetic asymmetries documented above are universal: they hold for shielding and non-shielding languages alike.

- (18) Predicted and non-predicted shielding patterns

	Context			Predicted?	Type	Description
	NV	$VN]_{\sigma}$	$V]_{\sigma}N$			
a.		✓		Yes	1	Shielding in $VN]_{\sigma}$ context only
b.	✓			Yes	2	Shielding in NV context only
c.	✓	✓		Yes	1,2	Shielding in $VN]_{\sigma}$ and NV
d.	✓	✓	✓	Yes	1,2	Shielding in all contexts
e.	✓		✓	No	-	Shielding in NV and $V]_{\sigma}N$ contexts
f.		✓	✓	No	-	Shielding in $VN]_{\sigma}$ and $V]_{\sigma}N$ contexts
g.			✓	No	-	Shielding in $V]_{\sigma}N$ context only

Pattern (18a), with shielding in the tautosyllabic anticipatory ( $VN]_{\sigma}$ ) context only, is predicted because in Type 1 systems the tautosyllabic anticipatory context is where contrasts in vocalic nasality are the least distinct. Pattern (18b), with shielding in the perseveratory (NV) context only, is predicted because in Type 2 systems the perseveratory context is where contrasts in vocalic nasality are the least distinct. Pattern (18c), with shielding in both the tautosyllabic anticipatory and perseveratory contexts, is predicted as these are the two contexts in which vocalic nasality contrasts are least distinct, for both Type 1 and Type 2 systems. And finally, pattern (18d), where shielding occurs in *all* contexts where we might expect vowels to be allophonically nasalized, is predicted; in these languages, contrasts in vocalic nasality must be maximally distinct.

All four predicted patterns are attested. Seven of the surveyed languages shield in the tautosyllabic anticipatory context only (19), forty-five shield in the perseveratory context only (20), eight

shield in both contexts (21), and six shield in all contexts (22).<sup>16</sup> Recall that the exact allophones produced by shielding vary by language in unpredictable ways: for example, while Kaapor (Garcia Lopes 2009) and many other languages use [mb] to shield in NV contexts (/m/ → [mb] / \_V), others (like Kakua, Cathcart 1979) use [b] (/m/ → [b] / \_V). The specific patterns given below are the allophones from the languages cited in the examples. For more details on the other languages, see sections 3.6.1–3.6.2.

- (19) Shielding in VN]<sub>σ</sub> only: 7 lgs., including Nadëb (Barbosa 2005):

<i>Schematic Description</i>	<i>Example</i>
a. /m/ → [bm] / V_C, V_#	[fə <b>dn</b> ] ‘hair’ (Barbosa 2005:45; translation mine)
b. /m/ → [m] / elsewhere	[napij̃] ‘sieve’ (Barbosa 2005:42; t.m.) [tanõ:h] ‘his mouth’ (Barbosa 2005:36, t.m.)

- (20) Shielding in NV only: 45 lgs., including Kaapor (Garcia Lopes 2009):

<i>Schematic Description</i>	<i>Example</i>
a. /m/ → [mb] / _V	[ <b>mb</b> ɔj] ‘cobra’ (Garcia Lopes 2009:48; t.m.)
b. /m/ → [m] / elsewhere	[pitun] ‘night’ (Garcia Lopes 2009:46; t.m.) [jamũ] ‘to groan’ (Garcia Lopes 2009:46, t.m.)

- (21) Shielding in VN]<sub>σ</sub> and NV: 8 lgs., including Karo (Gabas 1998):

<i>Schematic Description</i>	<i>Example</i>
a. /m/ → [bm] / V_C, V_#	[ko'rɛ <b>bm</b> ] ‘also’ (Gabas 1998:16; t.m.)
b. /m/ → [mb] / _V	[tah' <b>mb</b> ək] ‘all of them’ (Gabas 1998:14; t.m.)
c. /m/ → [m] / elsewhere	['nɔ̃p̃] ‘cable’ (Gabas 1998:14; t.m.)

- (22) Shielding in all contexts: 6 lgs., including Kaingang (Cavalcante 1987):

<i>Schematic Description</i>	<i>Example</i>
a. /m/ → [bm] / V_Ṽ, V_#	[pã'tɛ <b>dn</b> ] ‘surpass’ (Cavalcante 1987:39; t.m.)
b. /m/ → [mb] / #_V, Ṽ_V	[' <b>ndo</b> ] ‘arrow’ (Cavalcante 1987:39; t.m.)
c. /m/ → [bmb] V_V	[ko' <b>bmb</b> e] ‘broth’ (Cavalcante 1987:39; t.m.)
d. /m/ → [m] / elsewhere	[ka'dnã̃] ‘to smooth’ (Cavalcante 1987:39; t.m.)

The patterns in (18e–g) are not predicted, as shielding occurs in the heterosyllabic anticipatory context without also occurring in the perseveratory and the tautosyllabic anticipatory contexts. Since contrasts in vocalic nasality are expected to be more distinct in the heterosyllabic anticipatory context than in the perseveratory or tautosyllabic anticipatory contexts, languages that shield in the heterosyllabic anticipatory context should also shield in the other two contexts. As predicted by the contrast-based approach, the patterns in (18e–g) are unattested.

### 3.2.3 Incorporating the asymmetries

For the sake of analysis, I will assume here that the phonetics of Type 1 and Type 2 languages are as described in (15–16). These schematic figures are summarized below, as (23). Throughout, I will assume that nasal vowels in the contexts listed below (VN]<sub>σ</sub>, NV, and V]<sub>σ</sub>N) are fully nasal.

- (23) Assumed patterns of nasal coarticulation

a. Tautosyllabic anticipatory coarticulation (VN]<sub>σ</sub>)

(i) Type 1: 

V <sub>20</sub>	Ṽ <sub>80</sub>	N] <sub>σ</sub>
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<sup>16</sup>Why is shielding is found mostly in NV sequences? I'm not sure – one possibility is that languages with Type 2 phonetics are more common than languages with Type 1 phonetics (as is suggested by Table 3.1), and that shielding is often a strategy only used to avoid the most imperiled V–Ṽ contrasts (for reasons that are unclear).

- (ii) Type 2: 

V <sub>40</sub>	Ṽ <sub>60</sub>
-----------------	------------------

 N]<sub>σ</sub>
- b. Perseveratory coarticulation (NV)
- (i) Type 1: N 

Ṽ <sub>60</sub>	V <sub>40</sub>
------------------	-----------------
- (ii) Type 2: N 

Ṽ <sub>80</sub>	V <sub>20</sub>
------------------	-----------------
- c. Heterosyllabic anticipatory coarticulation (V]<sub>σ</sub>N)
- (i) Type 1: 

V <sub>60</sub>	Ṽ <sub>40</sub>
-----------------	------------------

 ]<sub>σ</sub>N
- (ii) Type 2: 

V <sub>60</sub>	Ṽ <sub>40</sub>
-----------------	------------------

 ]<sub>σ</sub>N

The attested typology of shielding patterns can be derived by defining MINDIST constraints that set varying thresholds of distinctiveness for contrasts in vocalic nasality. A constraint that requires oral vowels to be at least 50 units oral to be distinct from nasal vowels, for example, would penalize only the contrasts between oral vowels in (23a–b) and nasal vowels in those same environments.

An analytical question that arises at this point is the following: when we talk about partially nasalized vowels, should we describe them in terms of the *percentage* of acoustic nasality they exhibit, or rather in terms of the *absolute duration* of nasality? While referring to the percentage of acoustic nasality in a given vowel is likely relevant – it seems reasonable to believe that a longer vowel that is 50% nasalized will be perceived as less nasal than a shorter vowel that is 75% nasalized, even if the absolute duration of vocalic nasality in the two vowels is the same – this has not been shown. On the other hand, there is experimental and typological evidence that absolute duration of acoustic nasality is relevant to the perception of vocalic nasality. For example, Whalen & Beddor (1989) show that the longer the duration of a vowel with an intermediate level of nasalization, the more likely listeners are to identify it as nasal. This preference for long nasal vowels is reflected by a typological asymmetry: of the 12 languages included in Maddieson’s (1984) *Patterns of Sounds* that license contrasts in both vowel length and nasality, several license a contrast in nasality for long vowels only, but none license it for short vowels only (24).<sup>17</sup>

(24) Length and nasality contrasts in Maddieson (1984)

✓V- $\tilde{V}$ , ✓V:- $\tilde{V}$ :	*V- $\tilde{V}$ , ✓V:- $\tilde{V}$ :	✓V- $\tilde{V}$ , *V:- $\tilde{V}$ :
Irish, Hindi-Urdu, Lakkia, Navaho,	Breton, Ojibwa, Delaware	
Chipewyan, Tolowa, Auca, !Xu		

The analyses presented in this chapter make reference to absolute duration, rather than ratios of nasality. This however is not equal to a claim that *only* absolute duration is relevant: the hope is that, once we better understand the roles that absolute and relative durations of nasality play in the perception of vocalic nasality contrasts, both of these factors can be integrated into an analysis that better-reflects the relevance of more than just one cue.

### Languages with shielding in all contexts

To analyze systems in which shielding occurs in all contexts, all that is needed is a MINDIST constraint that requires an oral vowel to be fully oral, and a nasal vowel to be fully nasal, in order for the contrast between them to be sufficiently distinct. This constraint is NASDUR, originally defined in (9) and repeated as (25) below.

<sup>17</sup>Karok, an isolate spoken in Western California, appears to be an exception; however, the source (Bright 1957) does not accord nasal vowels phonemic status, and in any case does not claim that they are short.

- (25) MINDIST V- $\tilde{V}$  (NASDUR): for a contrast in vocalic nasality to be sufficiently distinct, the oral vowel must be fully oral and the nasal vowel must be fully nasal. Assign one violation for each violating pair.

Given this constraint, all contrasts in vocalic nasality adjacent to a nasal consonant will be dis-preferred, because oral vowels are nasalized in these environments (see (23)). Thus even in the heterosyllabic context, shielding will be motivated, as oral and nasal vowels are not fully distinct. See (26) for an illustrative tableau. I assume that the realized inputs for /amã/ and /ãmã/ are /a<sup>ã</sup>mã/ and /ãmã/, respectively. The output candidates considered here are the fully faithful (26a), which violates NASDUR; two shielding candidates, which violate \*CONTOUR (26b) and MAX[+nas] (26c); and the neutralizing (26d), which violates MAX[-nas]. As before, I do not consider any candidates in which an oral vowel adjacent to a nasal consonant is fully oral: I assume that these are ruled out by constraints on articulatory effort. For shielding to result, at least one of \*CONTOUR and MAX[+nasal] must be demoted beneath both NASDUR and MAX[-nasal]. Whether or not a contour segment results depends on the relative ranking of MAX[+nasal] and \*CONTOUR.

- (26) Sample tableau: shielding in the heterosyllabic context

	a <sup>ã</sup> mã ãmã	NASDUR	MAX[-nasal]	MAX[+nasal]	*CONTOUR
a.	a <sup>ã</sup> mã ãmã	*!			
b.	abmã ãmã				*
c.	abã ãmã			*	
d.	ãmã ãmã		*!		

### Languages with tautosyllabic and perseveratory shielding

To analyze systems where shielding occurs only in the tautosyllabic anticipatory and perseveratory contexts, we must assume that some languages place less stringent requirements on their contrasts in vocalic nasality. For example, a language might only require oral vowels to be at least 50 units oral for them to remain distinct from nasal vowels. This is a realistic assumption, as many languages license a contrast in vocalic nasality following nasal consonants, despite significant nasalization of oral vowels in this environment (e.g. Akan and French, in (23)).<sup>18</sup> A constraint enforcing this less stringent requirement is NASDUR<sub>≥50</sub>, defined in (27).

- (27) MINDIST V- $\tilde{V}$  (NASDUR<sub>≥50</sub>): for a contrast in vocalic nasality to be sufficiently distinct, the oral vowel must be at least 50 units oral and the nasal vowel must be fully nasal. Assign one violation for each violating pair.

In both Type 1 and Type 2 systems, NASDUR<sub>≥50</sub> is satisfied in the heterosyllabic anticipatory context only. This is because the heterosyllabic anticipatory context is the *only* context of the three in which vowels are more than 50 units oral; see (23). The result is that shielding is motivated in both the perseveratory and the tautosyllabic anticipatory contexts, as illustrated in (28–29). Because the oral vowel is less than 50 units oral, the contrast between it and a nasal vowel does not satisfy NASDUR<sub>≥50</sub>. In (28–29) and the tableaux that follow, a subscripted percentage either preceding or following the vowel denotes the number of units that are oral.<sup>19</sup>

<sup>18</sup>It is worth noting that the apparent permissiveness of French in this domain could be compensated for by the fact that at least some French nasal vowels differ in quality from their oral counterparts. It is not clear, however, that this is also true for Akan (the inventory provided by Maddieson 1984:292 does not suggest that the nasal and oral vowels differ in quality).

<sup>19</sup>What about an additional candidate in which the amount of coarticulatory nasalization has been decreased to 50% so as to render V- $\tilde{V}$  sufficiently distinct (e.g. [m<sup>ã</sup>a<sub>50%</sub>-mã]). I assume here that, in languages that exhibit shielding, an

- (28) NASDUR<sub>≥50%</sub> motivates shielding in the perseveratory context

	m <sup>̃</sup> a <sub>&lt;50</sub> m <sup>̃</sup> a	NASDUR <sub>≥50</sub>	MAX[-nasal]	MAX[+nasal]	*CONTOUR
a.	m <sup>̃</sup> a <sub>&lt;50</sub> m <sup>̃</sup> a	*!			
b.	mba m <sup>̃</sup> a				*
c.	ba m <sup>̃</sup> a			*	
d.	m <sup>̃</sup> a m <sup>̃</sup> a		*!		

- (29) NASDUR<sub>≥50</sub> motivates shielding in the tautosyllabic anticipatory context

	<50a <sup>̃</sup> m ãm	NASDUR <sub>≥50</sub>	MAX[-nasal]	MAX[+nasal]	*CONTOUR
a.	<50a <sup>̃</sup> m ãm	*!			
b.	abm ãm				*
c.	ab ãm			*	
d.	ãm ãm		*!		

In the heterosyllabic anticipatory context, however, oral vowels are more than 50 units oral. Therefore contrasts between these partially nasalized oral vowels and fully nasal vowels do not violate NASDUR<sub>≥50</sub>, and shielding is not motivated. The tableau in (30) illustrates.

- (30) NASDUR<sub>≥50</sub> does not motivate shielding in the heterosyllabic anticipatory context

	>50a <sup>̃</sup> mã ãmã	NASDUR <sub>≥50</sub>	MAX[-nasal]	MAX[+nasal]	*CONTOUR
a.	>50a <sup>̃</sup> mã ãmã				
b.	abmã ãmã				*!
c.	abã ãmã			*!	
d.	ãmã ãmã		*!		

### Languages with either perseveratory or tautosyllabic anticipatory shielding

To analyze systems in which shielding occurs in only one context, either perseveratory or tautosyllabic anticipatory, we have to assume that there are languages that place even less strict requirements on the distinctiveness of vocalic nasality contrasts. For example, a language might require its oral vowels to be minimally 30 units oral, for them to be sufficiently distinct from nasal vowels. While this sounds minimal, it's not an uncommon situation. For example, vocalic nasality is contrastive in the perseveratory context in French, even though oral vowels are significantly (over 70%) nasalized following nasal consonants (Cohn 1990; see Table 3.1). A constraint enforcing this requirement, NASDUR<sub>≥30</sub>, is defined in (31).

- (31) MINDIST V-<sup>̃</sup>V (NASDUR<sub>≥30</sub>): for a contrast in vocalic nasality to be distinct, the oral vowel must be at least 30 units oral and the nasal vowel fully nasal. Assign one violation for each violating pair.

Which contrast violates NASDUR<sub>≥30</sub> depends on whether the system is Type 1 or Type 2. For Type 1 systems: contrasts in the tautosyllabic anticipatory context violate NASDUR<sub>≥30</sub>, as oral vowels in the tautosyllabic anticipatory context are under 30 units oral. Contrasts in the perseveratory and heterosyllabic anticipatory contexts do not violate NASDUR<sub>≥30</sub>, as oral vowels in these contexts are over 30 units oral. Thus for Type 1 systems, NASDUR<sub>≥30</sub> motivates shielding in the tautosyllabic anticipatory context, as the nasalized oral vowels are not sufficiently distinct from nasal vowels (32).

additional faithfulness constraint (i.e. a gradient version of MAX[-nasal]) dominates NASDUR, making it impossible to decrease the amount of nasal coarticulation produced by the Phonetic Realization component.

- (32) Type 1:  $\text{NASDUR}_{\geq 30}$  motivates shielding in the tautosyllabic anticipatory context

$>_{30} \tilde{a} \tilde{m}$ $\tilde{a} \tilde{m}$	$\text{NASDUR}_{\geq 30}$	MAX[-nasal]	MAX[+nasal]	*CONTOUR
a. $>_{30} \tilde{a} \tilde{m}$ $\tilde{a} \tilde{m}$	*!			
b. $\tilde{a} \tilde{b} \tilde{m}$ $\tilde{a} \tilde{m}$				*
c. $\tilde{a} \tilde{b}$ $\tilde{a} \tilde{m}$			*	
d. $\tilde{a} \tilde{m}$ $\tilde{a} \tilde{m}$		*!		

For Type 2 systems: contrasts in the perseveratory context violate  $\text{NASDUR}_{\geq 30}$ , as oral vowels in the perseveratory context are under 30 units oral. Contrasts in the tautosyllabic and heterosyllabic anticipatory contexts do not violate  $\text{NASDUR}_{\geq 30}$ , as oral vowels in these contexts are over 30 units oral. Thus in this case,  $\text{NASDUR}_{\geq 30}$  motivates shielding in the perseveratory context only (33).

- (33) Type 2:  $\text{NASDUR}_{\geq 30}$  motivates shielding in the perseveratory context

$\tilde{m} \tilde{a}_{<30}$ $\tilde{m} \tilde{a}$	$\text{NASDUR}_{\geq 30}$	MAX[-nasal]	MAX[+nasal]	*CONTOUR
a. $\tilde{m} \tilde{a}_{<30}$ $\tilde{m} \tilde{a}$	*!			
b. $\tilde{m} \tilde{b} \tilde{a}$ $\tilde{m} \tilde{a}$				*
c. $\tilde{b} \tilde{a}$ $\tilde{m} \tilde{a}$			*	
d. $\tilde{m} \tilde{a}$ $\tilde{m} \tilde{a}$		*!		

At this point it is worth reiterating that the percentages used in all  $\text{NASDUR}$  constraints, as well as the finer points of the representations they assess, are not crucial. What is crucial are the cross-linguistic asymmetries in coarticulation documented in Table 3.1. Regardless of the exact extent of coarticulatory nasalization or the exact point at which nasalization in an oral vowel renders it indistinguishable from a nasal vowel, setting thresholds of distinctiveness with  $\text{MINDIST}$  constraints allows us to derive those and only those shielding patterns that obey the existing implicational laws.

### Local summary

In sum, the contrast-based approach makes a set of accurate predictions regarding contextual asymmetries in the typology of shielding. Specifically, it correctly predicts that shielding in some context  $C_1$  implies shielding in some context  $C_2$  if a contrast in vocalic nasality is more distinct in  $C_1$  than it is in  $C_2$ .  $\text{MINDIST}$  constraints naturally capture this generalization because they set thresholds at which contrasts are sufficiently distinct. If some contrast  $x$ - $y$  violates a given  $\text{MINDIST}$  constraint in some context  $C_1$ , then  $x$ - $y$  will also violate that  $\text{MINDIST}$  constraint in all contexts in which  $x$ - $y$  is equally or less distinct than it is in  $C_1$ . Put differently, if a language bans the implementation of  $x$ - $y$  in a context where it is relatively distinct, it must also ban the implementation of  $x$ - $y$  in all contexts where it is less distinct. As it is impossible to define a  $\text{MINDIST}$  constraint that penalizes only relatively distinct contrasts, there is no way to derive the unattested patterns in which shielding targets only the more distinct contrasts in vocalic nasality.

### 3.2.4 Language-internal asymmetries

A contrast-based analysis of shielding predicts that if a language limits shielding to certain contexts within the word, it should limit it to contexts where shielding helps the most, i.e. where contrasts in vocalic nasality are the least distinct. Above, we saw cross-linguistic evidence that this prediction is correct. This subsection provides further evidence by briefly considering asymmetries internal to the grammars of Krenak (Pessoa 2012), Aguaruna (Overall 2007), and Karajá (Ribeiro 2012).

## The role of stress in Krenak

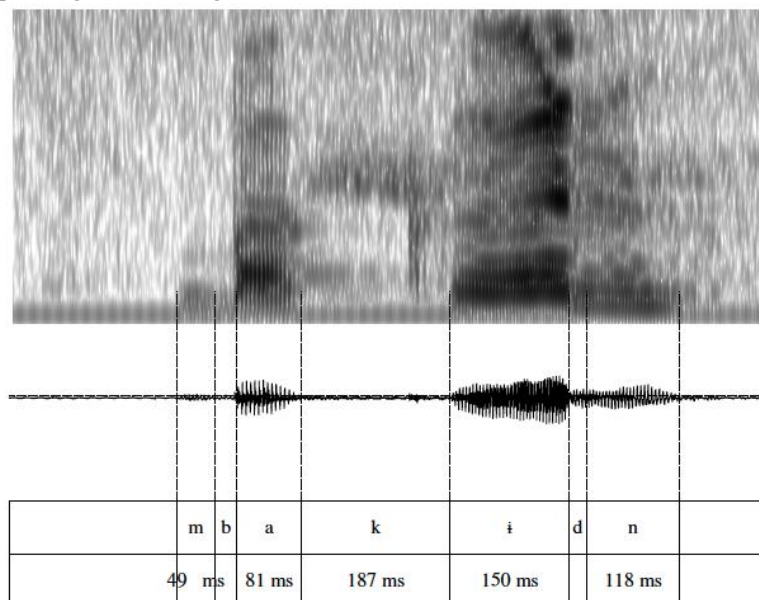
The shielding patterns of Krenak (Macro-Ge; Pessoa 2012) resembles those of Karitiâna to some degree, as shielding is licensed in all contexts (perseveratory, tautosyllabic anticipatory, and heterosyllabic anticipatory). But unlike Karitiâna, as well as most other systems, stress context plays a role in determining whether or not shielding occurs. Pessoa (2012:113) notes that shielding occurs more frequently in unstressed syllables than it does in stressed syllables – with the exception of shielding in the tautosyllabic anticipatory context (VN]<sub>σ</sub>), which tends to occur more frequently word-finally (Pessoa 2012:122). This is perhaps because consonants are lengthened in this position (as suggested by Figure 1 below), and thus better hosts for nasal contours. A couple examples of shielding in Krenak from Pessoa (2012:114–121) are provided in (34); gloss translations are mine.

### (34) Shielding in Krenak

- a. /amizik/ → [ambi'ʒik] ‘manioc’ cf. [am̃ʒ'ɨgut] ‘food’  
 b. /tõnɔn/ → [tõ'ndɔdñ] ‘small’ cf. [hi'nũñ] ‘his/her arm’

Why should a shielding process preferentially apply in stressless syllables? One answer to this question banks on a potential link between stress and duration: perhaps stressed vowels are consistently longer than stressless vowels in Krenak. Pessoa’s description of the language does not explicitly discuss any phonetic differences between stressed syllables and others, but a link between stress and increased duration has been found in other languages (see Hayes 1995:5–8 on cues to stress). In addition, primary stress in Krenak is word-final (Pessoa 2012:113), where vowel lengthening is cross-linguistically common regardless of any association with stress (Lehiste 1976, Lunden 2014). Some evidence for a durational asymmetry comes from the few phonetic measurements provided of disyllabic words, where there is a substantial difference between the durations of the word-initial and word-final vowels. A waveform of [m<sup>b</sup>aki<sup>d</sup>ñ] (‘little bird’), from Pessoa p. 96, is provided in Figure 1. At 150 ms., word-final [i] is almost twice as long as non-final [a]. This difference likely cannot be traced to an inherent durational asymmetry between [i] and [a], as we generally expect low vowels to be longer than high ones (Lehiste 1976).

Figure 3-1: Spectrogram and segmental durations for [mbakidñ] (‘little bird’), Pessoa 2012:96





If we assume that the amount of nasal coarticulation induced on a vowel adjacent to a nasal consonant is fixed, and does not depend on the vowel's length, then we would expect contrasts in vocalic nasality to be less distinct for short vowels than they are for long vowels. While a given amount of nasal coarticulation (say 75 units) might only take up a small portion of a long vowel (35), that same amount of coarticulation will take up comparatively more of a shorter vowel (36).

(35) Contrasts in vocalic nasality more distinct when vowels are long

a.	N	$\tilde{V}_{75}$	$V_{125}$
b.	N	$\tilde{V}_{200}$	

(36) Contrasts in vocalic nasality less distinct when vowels are short

a.	N	$\tilde{V}_{75}$	$V_{25}$
b.	N	$\tilde{V}_{100}$	

It is possible to motivate shielding in only (36) by defining a MINDIST constraint that considers the contrast between the long oral and nasal vowels in (35), but not the short oral and nasal vowels in (36), sufficiently distinct.  $NASDUR_{\geq 50}$ , defined in (30), will suit this purpose. As the contrast in (35) is between a fully nasal vowel and one that is 125 units oral,  $NASDUR_{\geq 50}$  is satisfied (37).

(37) Shielding is not motivated when vowels are long

	$m^{\tilde{a}}a_{125}$	$m\tilde{a}$	$NASDUR_{\geq 50}$	MAX[-nasal]	MAX[+nasal]	*CONTOUR
a.	$m^{\tilde{a}}a_{125}$	$m\tilde{a}$				
b.	$mba:$	$m\tilde{a}$				*!
c.	$ba:$	$m\tilde{a}$			*!	
d.	$m\tilde{a}:$	$m\tilde{a}$		*!		

The contrast in (36) violates  $NASDUR_{\geq 50}$ , however, as the oral vowel is only 25 units oral (38). Shielding is therefore motivated for short, but not long, vowels.

(38) Shielding is motivated when vowels are short

	$m^{\tilde{a}}a_{25}$	$m\tilde{a}$	$NASDUR_{\geq 50}$	MAX[-nasal]	MAX[+nasal]	*CONTOUR
a.	$m^{\tilde{a}}a_{25}$	$m\tilde{a}$	*!			
b.	$mba$	$m\tilde{a}$				*
c.	$ba$	$m\tilde{a}$			*	
d.	$m\tilde{a}$	$m\tilde{a}$		*!		

Thus the fact that Krenak exhibits greater frequency of shielding in stressless syllables is predicted by a contrast-based account, assuming a fixed duration of nasal coarticulation. If stressless vowels are shorter than stressed vowels, a given amount of nasal coarticulation will render a short oral vowel comparatively less distinct from a nasal vowel than it will a long oral vowel. The general explanation for the preference to shield in stressless syllables, then, receives the same explanation as the contextual asymmetries documented above: if a shielding process targets only a subset of contexts, it will target those contexts in which contrasts in vocalic nasality are the least distinct.

## The role of vowel quality in Aguaruna and Karajá

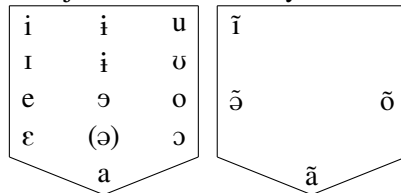
In Karajá (Macro-Ge, Ribeiro 2012), shielding occurs only in the perseveratory context.<sup>20</sup> What differentiates Karajá from other similar systems is that whether or not shielding occurs is also dependent on the quality of the following vowel: shielding largely does not occur before /a/. A similar pattern is attested in Aguaruna, where shielding is generally more likely when preceding high vowels, and almost entirely absent preceding a word-final /a/ (examples from Overall 2007:53).<sup>21</sup>

### (39) Shielding in Aguaruna

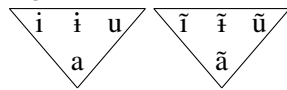
- a. /mama/ → [mamá] ‘mother’
- b. /nusi/ → [dúsi] ~ [ndúsi] ‘peanut’
- c. /natsa/ → [dátsa] ~ [ndátsa] ‘youth’

The vocalic inventories of Karajá (Ribeiro 2012:86) and Aguaruna (Overall 2007:40) are provided in (40) and (41), respectively. Note that, in both languages, /a/ is the only low vowel.

### (40) Karajá’s vowel inventory



### (41) Aguaruna’s vowel inventory



One possible interpretation of the dispreference to shield before /a/ is identical to the interpretation of the Krenak facts. Generally speaking, we know that low vowels are longer than higher vowels (Lehiste 1976). In Karajá, perhaps shielding does not occur adjacent to oral [a] because it is longer than all of the other oral vowels: in nasal contexts, assuming a fixed amount of nasal coarticulation, we would predict for the contrast between [a] and its nasal counterpart to be more distinct than are the other contrasts in vocalic nasality. In Aguaruna, the same general principles apply; although the context-specific ban on pre-[a] shielding in final position cannot be linked to any other known facts about Aguaruna’s phonology, it is not surprising, given the general prevalence of word-final lengthening in the world’s languages (Lehiste 1976, Lunden 2014). If word-final [a] is longer than other [a]s in Aguaruna, then the contrast between word-final [a–ã] in a nasal context will be more distinct than non-final [a–ã] in that same nasal context, and therefore less in need of enhancement. The significance here is that the subset of contexts targeted by shielding in Karajá and Aguaruna are those contexts in which contrasts in vocalic nasality are expected to be less distinct.<sup>22</sup>

<sup>20</sup>Ribeiro (2012) claims [m] and [n] are allophones of /b/ and /d/; the data are equally compatible with an interpretation under which [b] and [d] are allophones of /m/ and /n/, i.e. one in which the alternation is an example of shielding.

<sup>21</sup>This statement simplifies the details of what conditions Aguaruna shielding in some non-crucial ways. For a more complete discussion, see Overall 2007:52–57. Note also that Overall (p. 51–52) proposes that all nasal vowels can be derived from underlying VN sequences; see section 3.6.2 for discussion of this and other points.

<sup>22</sup>Note that the pattern in Karajá could also potentially be explained under the assumption that there is no contrast between oral [a] and nasal [ã]: both are allophones of /ã/. This proposal is consistent with historical evidence (see Ribeiro 2012:88–89 for discussion), but is difficult to reconcile with the fact that [a] and [ã] do appear to contrast in the contemporary lexicon (see Ribeiro 2012:88ff for discussion and near-minimal pairs).

### 3.2.5 Local summary

At this point, we have seen that a contrast-based analysis accurately predicts two generalizations regarding the typology of shielding. First, the existence of shielding in a given language implies the existence of a contrast in vocalic nasality. Second, if a language licenses shielding in a context where contrasts in vocalic nasality are more perceptible, it also licenses shielding in all contexts where they are less so. Next, I show that the contrast-based analysis also makes correct predictions regarding the typology of vowel nasalization contrasts.

## 3.3 Extensions: the typology of neutralization

Faced with an insufficiently distinct contrast, a language has two options: it can preserve the contrast through enhancement, or it can neutralize the contrast. So far, this chapter has focused only on enhancement, but the analysis developed here of the typology of shielding makes predictions regarding the typology of neutralization as well. Under a contrast-based analysis, both shielding and neutralization of vocalic nasality contrasts are motivated by the same set of MINDIST constraints. Whether we find shielding or neutralization depends on the ranking of other markedness and faithfulness constraints, with MINDIST satisfied in all cases. As shown below, if MAX[-nasal] dominates either \*CONTOUR or MAX[+nasal], the language will shield (42); if however \*CONTOUR and MAX[+nasal] dominate MAX[-nasal], the language will neutralize (43).

(42) Shielding when MAX[-nasal] >> \*CONTOUR, MAX[+nasal]

m <sup>a</sup> a m <sup>ã</sup>	NASDUR	MAX[-nasal]	*CONTOUR	MAX[+nasal]
a. m <sup>a</sup> a m <sup>ã</sup>	*!			
☞ b. mba m <sup>ã</sup>			*	
☞ c. ba m <sup>ã</sup>				*
d. m <sup>ã</sup> m <sup>ã</sup>		*!		

(43) Neutralization when \*CONTOUR, MAX[+nasal] >> MAX[-nasal]

m <sup>a</sup> a m <sup>ã</sup>	NASDUR	*CONTOUR	MAX[+nasal]	MAX[-nasal]
a. m <sup>a</sup> a m <sup>ã</sup>	*!			
b. mba m <sup>ã</sup>		*!		
c. ba m <sup>ã</sup>			*!	
☞ d. m <sup>ã</sup> m <sup>ã</sup>				*

Under a contrast-based analysis, shielding and neutralization are two sides of the same coin: both are strategies to avoid insufficiently distinct contrasts in vocalic nasality.

Given that shielding and neutralization are motivated by the same set of MINDIST constraints, the contrast-based analysis predicts that the same implicational laws that govern the distribution of shielding should also govern the distribution of contrasts in vocalic nasality. Recall that if shielding targets a vocalic nasality contrast in some context where the contrast is *more* distinct, it also targets this contrast in all contexts where it is *less* distinct. As a corollary, if neutralization targets a vocalic nasality contrast in some context where it is *more* distinct, it should also target this contrast in all contexts where it is *less* distinct (see Steriade 1997 and others cited in the introduction for evidence that this is true in other domains). More generally, the prediction is: if two contexts C<sub>1</sub> and C<sub>2</sub> differ in that some contrast x–y is better-cued in C<sub>1</sub> than it is in C<sub>2</sub>, then both enhancement and neutralization targeting x–y in C<sub>1</sub> must also target x–y in C<sub>2</sub>. In short, the typologies of shielding and neutralization of vocalic nasality contrasts should be identical (see also Flemming 2008a:32ff).

To test this prediction, I conducted a second survey, composed of all descriptive grammars from PL5000–PM7875 available on the shelves in MIT’s Hayden Library, as well as various sources available online. Of the languages in the sample, 98 licensed contrasts in vocalic nasality. In 32 of these, contextual restrictions on the distribution of these contrasts were explicitly discussed. Asymmetries in the typology of neutralization, for the most part, directly mirrored asymmetries in the typology of shielding (44). For a list of languages surveyed and information about the contexts of neutralization (where applicable), see section 3.6.2.

(44) Results from the neutralization survey

	Context of neutralization V/N_ V/_N] <sub>σ</sub> V/_] <sub>σ</sub> N			Predicted?	Attested?	Example
a.	✓			Yes	Yes (20)	Vai (Welmers 1976)
b.		✓		Yes	Yes (3)	Gbeya (Samarin 1966)
c.	✓	✓		Yes	Yes (2)	Kiowa (Watkins 1984)
d.	✓	✓	✓	Yes	Yes (5)	Kana (Ikoro 1996)
e.		✓	✓	No	Yes (2)	Tinrin (Osumi 1995)
f.	✓		✓	No	No	
g.			✓	No	No	

The two attested systems in (44e) appear to be problematic. Since we expect contrasts in vocalic nasality to be more distinct in the heterosyllabic context than in the perseveratory context, we should not expect to find any languages that neutralize vocalic nasality contrasts in both anticipatory contexts (V/\_N]<sub>σ</sub> and V/\_]<sub>σ</sub>N), to the exclusion of the perseveratory (V/N\_) context.

It is possible to show, however, that these counterexamples are only apparent. There is substantial evidence that Tinrin (Osumi 1995) has, or perhaps at some point had, a process of regressive nasal spreading. The first piece of evidence for this claim comes from Osumi’s (1995:24) discussion of restrictions on vocalic sequences. While sequences of both oral and nasal vowels are possible, there are restrictions on sequences of oral and nasal vowels. It is possible for a nasal vowel to precede an oral vowel (ṼV, e.g. [ɔ̃u] ‘head of yam’, Osumi p. 24), but it is impossible for an oral vowel to precede a nasal vowel (\*ṼṼ). In other words, contrasts in vocalic nasality are neutralized preceding nasal vowels. This is exactly what we would expect from a language that exhibits regressive [+nasal] spreading. Further evidence for a process of regressive nasal spreading comes from restrictions on vowel sequences across approximants ([w], [r~ɹ], and [ɹ]). Across these segments, vowels agree for nasality in the vast majority (91%, or 305/335) of cases (45); in other words, the approximant is bounded on both sides by oral (e.g. [aʏoɹo] ‘everywhere’, Osumi p. 76) or nasal (e.g. [aŋɔ̃ɹɔ̃] ‘five’, Osumi p. 46) vowels. The existing mismatches are almost exclusively ṼRV (e.g. [pʷārewē] ‘a series of waves’, Osumi p. 5): the general absence of VR̃Ṽ is, again, consistent with the activity of regressive [+nasal] spreading.

(45) Vowel sequences across approximants in Tinrin

	Match	Mismatch	
		ṼRV	VR̃Ṽ
#	305	26	4
<b>Total</b>	<b>305</b>	<b>30</b>	

Across voiceless obstruents, the rate of vowel nasality matches is much lower (43/66, or 65%). This suggests that the regressive spreading process applies much less consistently across stops,

if it applies in this context at all. More frequent application across sonorants is consistent with implicational laws governing the typology of nasal spreading: it is common for nasal spreading to apply across sonorants but not obstruents (e.g. Schourup 1973, Walker 2000).

The other language with neutralization of vowel nasality contrasts in both anticipatory contexts is Xârâcùù (Lynch 2002b), a close relative of Tinrin. While there is much less data available, in most VRV sequences (96%, or 48/50) the vowels match for nasality (46); also like Tinrin, vowels are less likely to match for nasality across voiceless stops (only 72%, or 23/32).<sup>23</sup>

(46) Vowel sequences across approximants in Xârâcùù

	Match	Mismatch	
		ŨRV	VRŨ
#	48	2	0
<b>Total</b>	<b>48</b>	<b>2</b>	

Neutralization of all pre-N vocalic contrasts in nasality in these two languages is not a reaction to insufficiently distinct contrasts, but a consequence of an unrelated process of unbounded regressive nasal spreading.<sup>24</sup> As progressive nasal spreading would be indistinguishable from neutralization of all post-nasal vocalic nasality contrasts, the pattern that we find in Tinrin and Xârâcùù is the only pattern that the possibility of nasal spreading adds to the predicted typology of neutralization.

### 3.4 Are there alternatives?

So far, this chapter has shown that analyzing environmental shielding as contrast preservation makes a set of strong and accurate predictions. The first prediction, verified in section 3.1, is that shielding should only be attested in languages that license a contrast in vocalic nasality: if there is no contrast to protect, then there is no motivation to shield. The second prediction, verified in section 3.2, is that shielding in a context where contrasts in vocalic nasality are more distinct implies shielding in all contexts where these contrasts are less distinct. The third prediction, verified in section 3.3, is that contextual asymmetries in the typologies of shielding and neutralization of vocalic nasality contrasts should be identical. Under a contrast-based analysis, the motivation driving the two phenomena is the same: both are strategies to avoid insufficiently distinct contrasts.

But there is one final question. This chapter has argued that a contrast-based analysis is an available analysis of the typology of shielding, but is it the *only* available one? In other words, is it possible to account for this set of generalizations *without* appealing directly to constraints on contrast? This section considers three alternative analyses. The first, discussed in section 3.4.1, claims that shielding arises from spreading of [-nasal] (e.g. Storto 1999:26-31, Eberhard 2004). The second, discussed in section 3.4.2, uses CUE constraints (Escudero & Boersma 2003, Boersma 2009) instead of directly referencing contrast; the third, discussed in section 3.4.3, treats shielding as a byproduct of *channel bias*, or innocent misapprehension (Ohala 1981, Blevins 2004, Moreton 2008). While these alternatives are capable of analyzing portions of the shielding typology, it is unclear how any of them in their current form could be extended to cover the full range of generalizations presented

<sup>23</sup>For Tinrin, the counts in (45) include all relevant forms in Osumi 1995; the counts for vowel nasality matches across voiceless obstruents are from the forms on pp. 1-100. For Xârâcùù, all relevant forms have been included for both counts. For both languages, forms transcribed variably (i.e. VRV on one page but ŨRV on another) have been excluded.

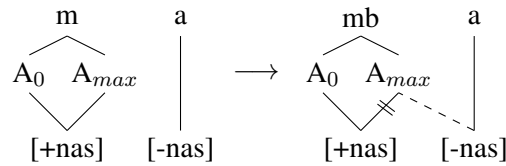
<sup>24</sup>To be clear, I assume here that unbounded nasal spreading is not motivated by constraints on contrast (though cf. e.g. Walker 2014:516). While there is not space to develop a full analysis of the Tinrin and Xârâcùù patterns here, one possibility is that they are triggered by a constraint like SPREAD-L([+nasal],PrWd) (after Walker 2000:44): for every [+nasal] autosegment *n*, assign one violation for every segment in *n*'s prosodic word that is to *n*'s left.

in this chapter. A very general failing of all these alternatives is that they fail to link the possibility of shielding to facts about the set of contrasts that a language licenses: they do not recognize that shielding is a form of contrast enhancement.

### 3.4.1 Spreading of [-nasal]

Aside from the contrast-based analysis of shielding developed above, the only other analysis that has been proposed in the literature claims that shielding arises due to local spreading of [-nasal] from an oral vowel onto (part of) a nasal stop (e.g. Storto 1999:26-31, Eberhard 2004). A case of shielding in the perseveratory context, for example, would be analyzed as in (47). Under this analysis, shielding is just an example of feature spreading; the notion of contrast plays no role.

(47) Shielding as spreading of [-nasal]<sup>25</sup>



There are, however, several reasons to believe that this analysis is a non-starter (beyond the more general arguments against allowing [-nasal] to spread, discussed by Steriade 1993b).

A spreading-based analysis does not predict the link between facts about the inventory (i.e. existence of a contrast in vocalic nasality) and facts about the phonotactics (i.e. possibility of shielding). As shown above, this is crucial to the analysis. While it might be possible to solve this problem by claiming that [-nasal] can spread only if [ $\pm$ nasal] is contrastive for vowels, the analysis would still have no explanation for contextual asymmetries in the shielding typology. The fact that shielding in the heterosyllabic context (V] <sub>$\sigma$</sub> N) universally implies shielding in the perseveratory context (NV), for example, would remain unexplained. Furthermore, a spreading-based analysis cannot predict that the typologies of shielding and contextual neutralization should mirror one another.

A variant of this analysis could claim that shielding is the result of gestural misalignment: shielding in the perseveratory context, for example (/ma/ → [mba]), occurs when velic closure precedes the release of the oral constriction. Like the spreading-based analysis, however, it is difficult for the gestural misalignment analysis to explain why the only languages that allow shielding also license a contrast in vocalic nasality. Furthermore, neither the contextual asymmetries in the typology of shielding, nor their parallels to the typology of neutralization, receive an explanation.

### 3.4.2 CUE constraints

The proposed analysis of shielding claims that it is crucial to explicitly reference contrast by appealing to acoustic properties that cue contrasts among different segments. Other approaches appeal to acoustic properties that cue the presence of individual feature values or segments, and make no reference to contrast. Here I explore how one such model, Boersma's (1998 *et seq.*) Parallel Bidirectional Phonology and Phonetics (BiPhon) model, might account for the shielding data presented in this chapter. We focus here mainly on the applicability of CUE constraints, which penalize correspondences between abstract phonological units (enclosed in slashes) and their phonetic realizations

<sup>25</sup> A<sub>0</sub> denotes the closure phase of the stop, and A<sub>max</sub> denotes the release; on Aperture Theory, see Steriade (1993a).

(enclosed in square brackets).<sup>26</sup> A schematic CUE constraint is defined in (48); it penalizes a correspondence between a vowel that is [-nasal] and a vowel that is nasalized for *X* or more units.

(48)  $*V/[X+ \textit{nasalized}]$ : assign one violation for each oral vowel that is nasalized for *X*+ units.

CUE constraints are claimed to be active in both perception and production. For perception, (48) penalizes the act of categorizing an *X*+ nasal vowel as [-nasal]. For production, (48) penalizes the act of producing a [-nasal] vowel with nasalization for *X*+ units of its duration.

An important aspect of the model is that CUE constraints can interact with more traditional markedness and faithfulness constraints. This means that instances of the schematic CUE constraint in (48) can motivate both shielding and neutralization. For example, consider a system with Type 1 phonetics (23): oral vowels are nasalized for 80 units in the tautosyllabic anticipatory ( $VN]_{\sigma}$ ) context, 60 in the perseveratory (NV) context, and 40 in the heterosyllabic ( $V]_{\sigma}N$ ) context. The CUE constraints  $*V/[80+ \textit{nasalized}]$ ,  $*V/[60+ \textit{nasalized}]$ , and  $*V/[40+ \textit{nasalized}]$  penalize oral vowels in nasal contexts according to the threshold of acceptable nasalization that they set. In (49), violations of  $*\text{CONTOUR}$  (penalizing shielding) and  $\text{MAX}[-\textit{nasal}]$  (penalizing neutralization) are recorded together, under M/F (MARKEDNESS/FAITHFULNESS). Recall that the subscripted percentage adjacent to an oralized nasal vowel represents the percentage of the vowel that is oral (I assume that additional articulatory constraints, not defined here, ensure the realization of the proper amount of nasal coarticulation on oral vowels in different nasal contexts).

(49) Cue constraints disprefer oral vowels adjacent to nasal consonants

/am/	$*V/[80+ \textit{nas}]$	$*V/[60+ \textit{nas}]$	$*V/[40+ \textit{nas}]$	M/F
a. $[20a^{\tilde{a}}m]$	*	*	*	
b. $[abm]$				*
c. $[\tilde{a}m]$				*
/ma/				
a. $[m^{\tilde{a}}a_{40}]$		*	*	
b. $[mba]$				*
c. $[m\tilde{a}]$				*
/amã/				
a. $[60a^{\tilde{a}}m\tilde{a}]$			*	
b. $[abm\tilde{a}]$				*
c. $[\tilde{a}m\tilde{a}]$				*

We can derive different patterns of shielding and neutralization by interleaving M/F within the hierarchy of CUE constraints. If M/F dominates  $*V/[40+ \textit{nas}]$ , then shielding or neutralization will be motivated in both the tautosyllabic anticipatory and perseveratory contexts (as vowels in these contexts are more than 40 units nasalized), but not the heterosyllabic anticipatory context (as vowels in this context are only 40 units nasalized). If M/F dominates  $*V/[60+ \textit{nas}]$ , then shielding or neutralization will be motivated only in the tautosyllabic anticipatory context. If M/F dominates all of the CUE constraints, shielding will never occur; if all CUE constraints dominate M/F, then shielding will occur in all nasal contexts. Whether shielding or neutralization is the preferred repair depends on the relative ranking of  $*\text{CONTOUR}$  and  $\text{MAX}[-\textit{nasal}]$  (evaluated above as M/F).

This analysis of shielding and neutralization has several strengths. As is the case with the contrast-based analysis developed in sections 3.1–3.2, the analysis invoking CUE constraints pre-

<sup>26</sup>For a general summary of how CUE constraints figure within the larger BiPhon model, see Boersma (2009).

dicts that if shielding targets an oral vowel that is more nasalized, it should also target an oral vowel that is less nasalized. Because oral vowels with longer durations of acoustic nasality incur a superset of the CUE constraint violations incurred by oral vowels with shorter durations of nasality, it is impossible to derive a pattern in which shielding applies only to avoid vowels with lesser degrees of nasalization. Furthermore, as both shielding and neutralization are motivated by the same set of CUE constraints, this analysis correctly predicts that the same implicational generalizations that hold for the typology of shielding should also hold for the typology of neutralization.

The analysis, however, fails to account for the generalization that shielding only occurs in languages that license a contrast in vocalic nasality. CUE constraints do not make reference to contrast: the constraint in (48) is applicable to all languages, regardless of whether or not they license a contrast in vocalic nasality. Although there are hints that the range of cues referenced by CUE constraints is dependent on the language's phonemic inventory (Hamann & Downing 2015:9, fn. 11; 17), this aspect of the theory has not been spelled out. While further theoretical developments may change this conclusion, at present the BiPhon model cannot account for the full set of generalizations presented in this chapter, as it does not make explicit reference to contrast.

### 3.4.3 Channel bias

The final alternative I discuss holds that shielding patterns emerge as a byproduct of channel bias (or *innocent misapprehension*; Ohala 1981, Blevins 2004, Moreton 2008). Under this alternative, shielding is not the result of enhancement, but rather of neutralization processes that have occurred as a result of misperception arising during language transmission (see also chapter 2.5.1 for a partial analysis of the distribution of phonemic nasal-stop sequences along these lines). For example, consider a language like Karajá (Ribeiro 2012:75), in which all syllables are open, and shielding occurs in the perseveratory context only. I will assume the segmental distribution in (50).

- (50) Hypothetical perseveratory shielding system
- a. Oral and nasal vowels contrast after voiceless consonants: ✓pã, ✓pa
  - b. Only oral vowels may follow NCs: ✓mba, \*mbã
  - c. Only nasal vowels may follow Ns: ✓mã, \*ma

The system in (50) could have developed from an earlier stage in which nasal and voiced prenasalized consonants were originally contrastive. Over time, however, oral vowels following nasal consonants could have been confused with, and reinterpreted as, nasal vowels ([m<sup>a</sup>a] → /mã/). In addition, prenasalized consonants preceding nasal vowels could have been confused with, and reinterpreted as, plain nasal consonants ([mbã] → /mã/). (For independent evidence that voiced prenasalized consonants preceding a nasal vowel are frequently misidentified as nasal consonants, see Beddor & Onsuwan 2003.) The system resulting from these changes would be one in which nasal and prenasalized consonants are in complementary distribution according to the quality of the vowel that follows them (as in (50)); see (51) for a summary.



(51) Proposed historical source of the distribution in (50)

[mã]		
	<i>nasalization causes [ã] to be perceived as [ã]</i>	
[mã]	<i>nasal vowel causes [mb] to be perceived as [m]</i>	[mã]
[mbã]		
		[mba]
[mba]		

While a channel bias account is able to predict the development of relatively simple complementary distributions like the one schematized in (50), it faces a number of problems in accounting for the more complex patterns attested in the typology. I will discuss two such problems here.

First, it is unclear how a theory like the one above would be able to account for systems in which shielding occurs in only a subset of the contexts in which it could possibly occur. Consider for example those systems in which shielding occurs in only the tautosyllabic anticipatory (i.e. coda) context (i.e. Nadëb, Barbosa 2005). In these systems, both oral and nasal vowels can follow oral and nasal consonants, but shielding results when a coda nasal is preceded by an oral vowel (52).

(52) Hypothetical tautosyllabic anticipatory system

- Oral and nasal vowels contrast following oral consonants: ✓pã, ✓pa
- Oral and nasal vowels contrast following nasal consonants: ✓mã, ✓ma
- Only oral vowels may precede CNs: ✓abm, \*ãbm
- Only nasal vowels may precede Ns: ✓ãm, \*am

A channel bias account of these facts would assume that the historical starting point for the system in (53) was a language in which a contrast between nasal and preoralized nasal consonants co-existed with a contrast in vocalic nasality. Over time, however, oral vowels preceding nasal consonants would be confused with, and reinterpreted as, nasal vowels ([a<sup>ã</sup>m] → /ãm/). Preoralized stops following nasal vowels would be confused with, and reinterpreted as, plain nasals ([ãbm] → /abm/).

(53) Proposed historical source of the distribution in (52)

[ãm]		
	<i>nasalization causes [ã] to be perceived as [ã]</i>	
[a <sup>ã</sup> m]	<i>nasal vowel causes [bm] to be perceived as [m]</i>	[ãm]
[ãbm]		
		[abm]
[abm]		

But if the system in (52) is one in which nasal and preoralized nasal consonants originally contrasted, why are preoralized segments no longer attested in any context? Why, for example, do we not find an intervocalic contrast between /abmã/ and /amã/ in Nadëb, or indeed any other language with the shielding pattern in (53)? To explain why a language that displays the shielding pattern in (53) should ban /bm/ elsewhere, it would be necessary to postulate an additional markedness constraint that bans the occurrence of /bm/ in all prevocalic contexts: a constraint like \*CN/\_V (54), for

example, would prevent both [bma] and [abma] from surfacing, but crucially allow [abm] to exist.

(54) \*CN/\_V: assign one violation for each prevocalic CN sequence.

But the proposal that a language can ban preoralized segments in prevocalic position only becomes problematic when we consider how preoralized segments pattern in languages where they contrast with other segment types. In the two clear cases discussed by Poser (1979:32-35) where a contrast is licensed between preoralized segments and other kinds of stops (Nemi, and the Arandic languages of Australia), preoralized segments are allowed *only* in prevocalic position.<sup>27</sup> While the data are limited, a constraint banning postnasals from only prevocalic position does not provide an accurate characterization of the existing typology: it predicts an unattested pattern in which phonemic preoralized segments are allowed in coda position only. The contrast-based analysis presented in sections 2 and 3 avoids this problem, as it does not need to employ contextual markedness constraints to characterize a pattern like Nadëb: shielding in coda position only results from an interaction between MINDIST and context-free \*CONTOUR (see section 3.3.3). Without appealing to a constraint like \*CN/\_V, it is unclear how the pattern in Nadëb – where [bm] and [m] both appear finally, but do not contrast prevocalically – could be derived under a channel bias account.

A second hardship that a channel bias account faces becomes apparent when we consider the set of allophones produced by shielding in Karitiâna (Storto 1999). In Karitiâna, recall that nasal consonants are phonetically realized as medionasals when they appear between two oral vowels (/ama/ → [abmba]; though cf. Everett 2007 on variation between [bmb], [b], and [mb]). An analysis in which shielding arises as a result of contextual neutralization would have to assume that medionasals were originally contrastive with plain nasals. The complementary distribution between medionasals and other kinds of (partially) nasal segments would arise through neutralization of consonantal and vocalic nasality contrasts, in different contexts. (The other possibility, in which /ama/ was misperceived as /abmba/ due to a lack of nasal coarticulation, is not consistent with what we know about Karitiâna: according to Everett 2007, vowels adjacent to nasal consonants are regularly nasalized when shielding fails to apply.) As medionasals are unattested outside of shielding phenomena, however, proposing that they contrast(ed) with other stops at any point in any language's history is undesirable: we do not know of any languages in which the markedness constraint banning medionasals is subordinated to faithfulness constraints.<sup>28</sup> More succinctly, the channel bias account of shielding must assume that *all* allophones produced by shielding were at one point contrastive. Especially in the case of medionasals, this is not a desirable assumption.

The fundamental problem is that the channel bias account is only capable of deriving patterns of neutralization, not patterns of enhancement (though cf. Blevins 2004:285-289). And while some specific instances of enhancement can be reanalyzed as arising via neutralization, like the simple prevocalic shielding example in (50), this is not true of the entire typology.

<sup>27</sup> A potential exception discussed by Poser (1979) is Wolof, claimed by Ward (1939) to allow preoralized segments in final position only. But neither Ka's (1994) description of Wolof phonology nor acoustic data available from the UCLA Phonetics Lab Archive (2007) suggest that preoralization/nasal plosion exists in Wolof at all (see also Poser 1979:34-35).

<sup>28</sup> Can the lack of contrastive medionasals be derived under the proposed account of shielding? Not without further modifications to the analysis: there is currently nothing built into the system that would prevent medionasals from contrasting with other kinds of stops. The point of note here is that the diachronic analysis sketched above *requires* us to posit the existence of contrastive medionasals, but the contrast-based analysis does not.

## 3.5 Extensions and Conclusions

In sum, this chapter has argued that any successful analysis of the typology of shielding in South American languages must explicitly reference contrast. Before concluding, this section provides a brief discussion of two necessary areas of further research: an additional prediction of the proposed analysis regarding contextual restrictions on the distribution of shielding (section 3.5.1); and support for the analysis beyond the typological survey discussed in sections 3.2 and 3.3 (section 3.5.2).

### 3.5.1 Further predictions

In many cases, languages do not license vocalic nasality contrasts at all positions within the word: in Wari' (Chapakuran; Everett & Kern 1997), for example, the vocalic nasality contrast is licensed only in stressed syllables. Under the assumption that MINDIST constraints compare only sounds that occur in the same context, the analysis proposed above predicts that the distribution of shielding should track these positional asymmetries, where they exist. In other words, shielding should only be licensed in environments where there is a contrast in vocalic nasality to protect. Is this prediction borne out? The answer appears to be yes: although descriptions are often not clear about contextual limitations on contrasts in vocalic nasality, in the five surveyed cases where it is extremely likely that contextual restrictions exist (Kaapor, Garcia Lopes 2009; Karo, Gabas 1998; Myky, Montserrat 2010; Nadëb, Barbosa 2005; Wari', Everett & Kern 1997), shielding applies only in contexts where the contrast in vocalic nasality is licensed (see section 3.6.2 for details).

There are other ways in which shielding does not – and may not be expected to – track the distribution of vocalic nasality contrasts. For example, whether or not shielding applies before a given oral vowel does not appear to be sensitive to whether or not that oral vowel has a nasal correspondent. In Karajá, for example, shielding applies before [ɪ], [i], and [ʊ], despite the fact that nasal [ĩ], [ĩ̃], and [ũ] do not exist (see examples in Ribeiro 2001:79). More broadly, for 26/66 of the shielding languages surveyed, the inventory of oral vowels is larger than the inventory of nasal vowels (vowel inventories are provided in section 3.6.2); none of the descriptions, however, mention that shielding fails to occur before oral vowels that lack a nasal correspondent. This lack of sensitivity to whether a given oral vowel has a contrasting nasal correspondent is in fact predicted by the current analysis: the family of MINDIST constraints referred to as NASDUR do not take into account the quality of the vowels that they evaluate (see (55), repeated from (8)). From the standpoint of NASDUR, the contrast between [m<sup>̃</sup>ʊ] and [mũ] is just as (in)distinct as is the contrast between [m<sup>̃</sup>u] and [mũ]: in both cases, the contrast is between a partially nasalized and a fully nasalized vowel. The analysis thus predicts that if nasality is contrastive for some vowel quality, shielding is motivated when a nasal consonant is adjacent to an oral vowel of any quality (56).

- (55) MINDISTV- $\tilde{V}$  = NASDUR<sub>100%</sub>: for a contrast in vocalic nasality to be sufficiently distinct, the oral vowel must be fully oral and the nasal vowel must be fully nasal. Assign one violation for each violating pair.

	m <sup>̃</sup> ʊ mũ	NASDUR <sub>100%</sub>	MAX[-nasal]	MAX[+nasal]	*CONTOUR
a.	m <sup>̃</sup> ʊ mũ	*!			
(56) b.	mbʊ mũ				*
c.	bʊ mũ			*	
d.	mũ mũ		*!		

One topic for further research, then, is to determine the ways in which shielding and other forms of enhancement are sensitive to distributional restrictions on the contrast that they serve to enhance.

These generalizations have the potential to teach us both about what the form of constraints on contrast should be, as well as what kind of representations they should evaluate. For some further discussion, see Chapter 5.2.3.

### 3.5.2 Shielding outside of South America

As noted at the outset, the generalizations regarding the typology of shielding that have been established in this chapter are based on a survey of South American languages. In order for the conclusions drawn here to hold universally, evidence that the reported generalizations hold across a more geographically diverse sample of languages would be required.

While the investigation necessary to provide this evidence is beyond the scope of this chapter, a cursory examination of languages from other regions reveals some that license both shielding and a contrast in vocalic nasality (e.g. Slave, Na-Dené; Rice 1989:58–60<sup>29</sup>; Taiwanese Southern Min, Sino-Tibetan; Wang 2016), as well as several others that appear to allow shielding without licensing a contrast in vocalic nasality. These latter systems are problematic for the theory advanced here, and the two I know of are discussed below. In both cases, the shielding-type effects observed are best analyzed as a symptom of a different kind of process altogether, which affects more segments than just nasals. In other words, the processes discussed below are not examples of shielding; for now, then, the prediction that all shielding languages also license a contrast in vocalic nasality is upheld.

#### Prestopping in Australian languages

Prestopping, attested mainly in Australian and Austronesian languages, appears superficially similar to shielding – with the difference that prestopping frequently occurs in languages that lack a contrast in vocalic nasality. To illustrate, examples of prestopping from Arabana-Wangkangurru (Hercus 1972:296) are provided in (57). Where ‘Common Australian’ has an intervocalic nasal, Arabana-Wangkangurru has a prestopped intervocalic nasal.

(57) Prestopping in Arabana-Wangkangurru (Hercus 1972:296)

	<i>Common Australian</i>	<i>Arabana-Wangkangurru</i>	<i>Gloss</i>
a.	tyina	thidna	‘foot’
b.	kuna	kudna	‘feces’

But this is not the whole picture: in Arabana-Wangkangurru, as well as many other languages that exhibit nasal prestopping, laterals are prestopped as well (where Common Australian has *mulu/mila*, for example, Arabana-Wangkangurru has *midla*). This suggests that the alternations in (57) instantiate a process that is distinct from the class of shielding processes discussed above. As defined in section 3.2, shielding targets only nasals; prestopping is capable of targeting a larger class of sonorants. The two kinds of process also clearly have different motivations: prestopping does not appear to be motivated by a desire to protect the orality of a preceding vowel, as we expect vowels preceding laterals to be fully oral. The notion that prestopping has nothing to do with protecting the orality of a preceding vowel is supported by reports that prestopping of nasal consonants can occur after nasal vowels in Stieng (Austro-Asiatic) and Thai (Tai-Kadai) (Poser 1979:43–44).

Following Steriade (1993b), I hypothesize that prestopping occurs to enhance a syntagmatic sonority contrast between a stressed vowel and the consonant that immediately follows it. In lan-

<sup>29</sup>Rice (1989:83) claims that all nasal vowels can be derived from *Vn* sequences in conservative Slave. There is no evidence however that this generalization is psychologically real, i.e. that speakers are aware of the source of nasalized vowels, and changes in the Slavey dialect point to nasal vowels having acquired phonemic status (Rice 1989:83ff).

guages that license prestopping, the allophonic variation is frequently or always limited to immediately post-tonic position. Steriade (1993b) links this restriction to Edwards & Beckman (1988)’s suggestion that stress “induces a hypercharacterization of the sonority contrasts within the syllable”, and proposes that, in processes of prestopping, “the sonority contrast is being exaggerated by turning the coda consonant into an obstruent” (Steriade 1993b:343 for both). Shielding and prestopping may share similar surface manifestations, but the pressures that motivate them are distinct.

It is possible to tell the difference between the shielding processes discussed earlier in this chapter and the prestopping processes discussed here because they have different typological signatures: prestopping processes share a number of characteristics (outlined by Steriade 1993b:342) that shielding processes do not. For example, as discussed above, prestopping processes frequently target both nasals and laterals. In addition, processes of prestopping target only long or lengthened sonorants: either those that are underlyingly geminate (as in Icelandic, Einarsson 1945) or predictably lengthened (as in Arabana-Wangkangurru). This is not the case for shielding, where there is no clear link between shielding and the duration of the consonant that it targets. While it is unclear what causes prestopping processes to exhibit some of the characteristics that they do (e.g. the preference to target long consonants, but see Steriade 1993b:343 for a hypothesis), these are questions best left for future work. The important point is that while processes of prestopping may superficially resemble processes of shielding, a closer look at the typology reveals that they are best treated as a different kind of process, with a distinct motivation and a distinct surface manifestation.

### Denasalization in Korean

As documented by a number of scholars, Korean word-initial nasal consonants are partially denasalized, with the resulting segment acoustically and aerodynamically similar (but not identical) to a voiced obstruent at the same place of articulation (see e.g. Cho & Keating 2001, Kim 2011 on the phonetics of denasalization). Korean does not license a contrast in vocalic nasality; for further description of Korean phonetics and phonology, see Kim (2011) and references there.

But just as in the case of prestopping discussed above, there is evidence that the word-initial denasalization process observed in Korean is just one symptom of a more general process. In the case of Korean, Cho & Keating (2001) have shown that denasalization is part of a more general *domain-initial strengthening* process (Fougeron & Keating 1996 *et seq.*) which likely affects the realization of all obstruents in word-initial position.<sup>30</sup> Cho & Keating (2001) show that each of the Korean coronal stops – /n/, /t/, /t<sup>h</sup>/, and /t\*/, where /t\*/ represents the tense, or fortis, stop – undergoes fortition, or obstruentization, when in word-initial position: the consonants are lengthened, they evidence greater linguopalatal contact, the VOTs for /t/ and /t<sup>h</sup>/ increase, the nasal energy associated with /n/ decreases, etc. (see Cho & Keating 2001 on these and other measurements).

The point here is that, as for the cases of prestopping above, denasalization in Korean does not require and should not be given an independent explanation. Denasalization merely represents one side effect of a more general process – here, the fortition of all stops in word-initial position.

### 3.5.3 Summary

The major finding of this chapter is that constraints on contrast are essential to the analysis of environmental shielding in South American languages. In sections 3.1–3.3, I showed that the contrast-

<sup>30</sup>Kim (2011) disputes the claim that denasalization in Korean is a form of domain-initial strengthening on the grounds that, in her data, nasals at different levels of the prosodic hierarchy do not behave any differently from one another. She does not discuss the connections between denasalization and stop fortition established by Cho & Keating (2001).

based analysis is capable of predicting three typological generalizations that characterize a large set of South American languages: (i) shielding occurs only in languages with a contrast in vocalic nasality; (ii) if shielding targets a contrast in vocalic nasality that is relatively distinct, it targets all contrasts in vocalic nasality that are less so; and (iii) asymmetries in the typologies of shielding and neutralization mirror each other exactly. Though this last result is naturally predicted by contrast-based theories such as Dispersion Theory, evidence for parallels between the typologies of neutralization and enhancement phenomena has previously proven elusive (see Flemming 2008a:32–35; see also Chapter 2 for more evidence along these lines).

In section 3.4, I argued that the three conceivable alternative analyses of the shielding typology that do not explicitly refer to contrast (involving: spreading of [-nasal], CUE constraints, and channel bias) all make unwanted predictions that are avoided under a contrast-based analysis. Thus given the apparent lack of a workable alternative, we can conclude two things. First, environmental shielding is contrast preservation: contrast must play a central role in any successful analysis of the typology of shielding. Second, and more broadly, these results provide strong evidence that contrast and the constraints that reference it are an essential part of phonological theory. The hope is that pursuing the areas for further research outlined in sections 3.5.1–3.5.2 will serve to strengthen this result.

### 3.6 Appendix A: information on the shielding survey

This appendix contains a list of shielding languages (section 3.6.1), more detailed information on each of the languages listed (section 3.6.2), and a list of languages surveyed that do not exhibit shielding (section 3.6.3). In section 3.6.1, if a cell is shaded, it means that shielding occurs in that context. If the cell is not shaded, then shielding is not known to occur in that context. The column labeled “Evidence” summarizes the type of evidence found for a vocalic nasality contrast, in addition to the author’s description (MP = minimal or near-minimal pairs; NVNE = nasal vowels in non-nasal environments; – = no additional evidence available). The language names provided in this appendix are those used by SAPHon (Michael et al. 2012).

#### 3.6.1 List of shielding languages

Table 3.2: List of shielding languages

Evidence	Shielding contexts			Language (Family) Source	Location in 3.6.2
	NV	VN] <sub>σ</sub>	V] <sub>σ</sub> N		
MP				Aché (Tupí) Roessler 2008	#1, p. 106
MP				Aguaruna (Jivaroan) Overall 2007	#2, p. 107
MP				Amahuaca (Panoan) Osborn 1948	#3, p. 108
MP				Amarakaeri (Harakmbet) Tripp 1955	#4, p. 108
MP				Amundava (Tupí) Sampaio 1998	#5, p. 108
MP				Andoke (Isolate) Landaburu 2000a	#6, p. 109
MP				Apiaká (Tupí) Padua 2007	#7, p. 109
MP				Apinayé (Macro-Ge) Oliveira 2005	#8, p. 110
–				Arára do Mato Grosso (Isolate) da Rocha D’Angelis 2010	#9, p. 110
MP				Arikapú (Macro-Ge) Arikapú et al. 2010	#10, p. 111
NVNE				Asurini do Xingú (Tupí) Pereira 2009	#11, p. 111
MP				Avá-Canoeiro (Tupí) Borges 2006	#12, p. 112
MP				Barí (Chibchan) Mogollón 2000	#13, p. 112
MP				Chimila (Chibchan) Malone 2006, 2010	#14, p. 113

Evidence	Shielding contexts			Language (Family) Source	Location in 3.6.2
	NV	VN] <sub>σ</sub>	V] <sub>σ</sub> N		
MP				Chiriguano, Chané (Tupí) Dietrich 1986	#15, p. 113
MP				Chiriguano, Izoceño (Tupí) Dietrich 1986	#16, p. 113
MP				Dâw (Nadahup) Martins 2004	#17, p. 115
NVNE				Epena (Choco) Harms 1984	#18, p. 115
MP				Hup (Nadahup) Epps 2008	#19, p. 116
MP				Jabutí (Macro-Ge) Ribeiro & van der Voort 2010	#20, p. 116
NVNE				Júma (Tupí) Abrahamson & Abrahamson 1984	#21, p. 117
NVNE				Kaapor (Tupí) Garcia Lopes 2009	#22, p. 117
NVNE				Kaingang, São Paulo (Macro-Ge) Cavalcante 1987	#23, p. 118
NVNE				Kakua (Kakua-Nukak) Cathcart 1979	#24, p. 118
NVNE				Karajá (Macro-Ge) Ribeiro 2012	#25, p. 119
MP				Karapanã (Tucanoan) Metzger & Metzger 1973	#26, p. 120
MP				Karitiâna (Tupí) Storto 1999; Everett 2007	#27, p. 120
MP				Karo (Tupí) Gabas 1998	#28, p. 121
NVNE				Kotiria (Tucanoan) Waltz & Waltz 1972	#29, p. 121
MP				Krahô (Macro-Ge) Popjes & Popjes 2009	#30, p. 122
NVNE				Krenak (Macro-Ge) Pessoa 2012	#31, p. 122
NVNE				Krinkati-Timbira (Macro-Ge) Alves 2004	#32, p. 123
MP				Kubeo (Tucanoan) Chacon 2012	#33, p. 123
MP				Mako (Salivan) Labrada 2015	#34, p. 124
MP				Makuráp (Tupí) Braga 1992	#35, p. 124
MP				Mamaindé (Nambiquaran) Eberhard 2009	#36, p. 125



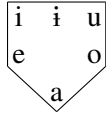
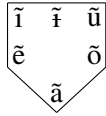
Evidence	Shielding contexts			Language (Family) Source	Location in 3.6.2
	NV	VN] <sub>σ</sub>	V] <sub>σ</sub> N		
NVNE				Maxakalí (Macro-Ge) Campos 2009	#37, p. 125
NVNE				Mbyá (Tupí) Thomas 2014	#38, p. 126
NVNE				Mebengokre (Macro-Ge) Salanova & Silva 2011	#39, p. 126
MP				Mundurukú (Tupí) Picanço 2005	#40, p. 127
MP				Myky (Isolate) Montserrat 2010	#41, p. 127
MP				Nadëb (Nadahup) Barbosa 2005	#42, p. 128
MP				Nhandeva (Tupí) Costa 2007	#43, p. 128
MP				Nukak (Kakua-Nukak) Mahecha et al. 2000	#44, p. 129
NVNE				Pai Tavytera (Tupí) Cardoso 2008	#45, p. 129
MP				Piratapuyo (Tucanoan) Klumpp & Klumpp 1973	#46, p. 130
MP				Poyanáwa (Panoan) De Paula 1992	#47, p. 130
MP				Puinave (Isolate) Girón 2007	#48, p. 131
MP				Secoya del Aguarico (Tucanoan) Johnson & Levinsohn 1990	#49, p. 131
MP				Secoya del Putumayo (Tucanoan) Vallejos 2013	#50, p. 132
NVNE				Sharanawa (Panoan) Pike & Scott 1962	#51, p. 132
NVNE				Sirionó (Tupí) Gasparini 2012	#52, p. 133
MP				Suyá (Macro-Ge) Guedes 1993	#53, p. 133
MP				Tapayuna (Macro-Ge) Camargo 2010	#54, p. 134
MP				Tenharim (Tupí) Sampaio 1998	#55, p. 134
NVNE				Ticuna (Isolate) Montes Rodríguez 2005	#56, p. 135
NVNE				Tupinambá (Tupí) Jensen 1984; Moore et al. 1993	#57, p. 135
MP				Uru-Eu-Wau-Wau (Tupí) Sampaio 1998	#58, p. 136

Evidence	Shielding contexts			Language (Family) Source	Location in 3.6.2
	NV	VN] <sub>σ</sub>	V] <sub>σ</sub> N		
MP				Waimaha (Tucanoan) Stolte & Stolte 1976	#59, p. 136
NVNE				Wari' (Chapakuran) Everett & Kern 1997	#60, p. 137
NVNE				Wayampi, Alto Jarí (Tupí) Jensen 1984	#61, p. 137
NVNE				Wayampi, Ampari (Tupí) Jensen 1984	#62, p. 138
NVNE				Xavánte (Macro-Ge) Quintino 2000	#63, p. 138
MP				Xetá (Tupí) Vasconcelos 2008	#64, p. 139
–				Yagua (Peba-Yaguan) Peña 2009	#65, p. 139
MP				Yuhup (Nadahup) Martins 2005	#66, p. 140

### 3.6.2 Additional information on each shielding language

Here I provide more information about each of the surveyed shielding languages. The page number for each language can be found in Table 3.2, in section 3.6.1. Additional information for each language, where I thought it was potentially relevant, is provided beneath the table.

#### #1: Aché (Tupí; Roessler 2008)

<i>Shielding contexts</i>	Prevocalic (NV → NDV, DV)
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V–Ṽ?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, tʃ, k NASAL: m, n, ɲ, ŋ

The oral allophone licensed by shielding depends to some extent on vocalic context: ND occurs only between a nasal and an oral vowel. D also occurs in this context, as well as all other oral contexts. In addition, the distribution of NDs is mostly limited to stressed syllables (p. 45):

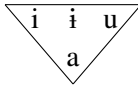
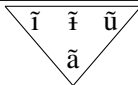
*“A primeira observação importante é que o contorno nasal das pré-nasalizadas é muito curto. Essencialmente em sílabas átonas a nasalidade desaparece.”*

There appears to be reduction in stressless syllables, which may be explain why more Ds are attested in this context (p. 45):

*“Note-se que em sílabas átonas, entre duas vogais orais, as oclusivas sonoras podem se realizar como aproximantes ou fricativas totalmente orais. . .”*

Nasal vowels do not appear to be limited to any particular position.

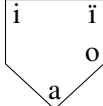
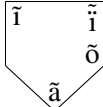
## #2: Aguaruna (Jivaroan; Overall 2007)

<i>Shielding contexts</i>	Prevocalic (NV → NDV, DV)
<i>Variability?</i>	Yes
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, ts, tʃ, k, ? NASAL: m, n

Regarding nasal vowels: Overall (2007:51–52) notes that all  $\tilde{V}$ s can be derived from underlying VN sequences. But there is no evidence that  $\tilde{V}$  is derived synchronically from VN: VN could just as well be the historical source of  $\tilde{V}$ .

Regarding details of shielding: word-internally, NDs are the preferred oral variant. In word-initial position, Ds and NDs are in free variation. In some lexical items shielding is compulsory, while in the rest of the lexicon it is optional. Shielding typically does not occur when the N is followed by a single word-final /a/; it is more likely to occur when the N precedes a high vowel or when it is word-initial, followed by a single vowel (i.e. not a diphthong). Shielding is also prohibited when it would result in the creation of two successive NCs (\*NCVNC); see p. 53 of Overall for more discussion of all of these points.

## #3: Amahuaca (Panoan; Osborn 1948)

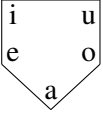
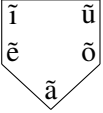
<i>Shielding contexts</i>	Prevocalic (NV → NDV)
<i>Variability?</i>	None mentioned
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, k, ? NASAL: m, n

Osborn (p.48), on the distribution of shielding:

*“The nasals m and n are voiced [...] The allophone nasal plus homorganic voiced stops occurs before oral vowels when the nasal occurs other than in morpheme initial or following another consonant...”*

In addition, there appear to be no restrictions on the distribution of nasal vowels (Osborn p. 189).

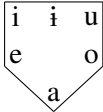
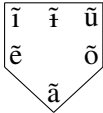
#### #4: Amarakaeri (Harakmbet; Tripp 1955)

<i>Shielding contexts</i>	Prevocalic (NV → NDV) Coda (VN] <sub>σ</sub> → VDN] <sub>σ</sub> ) Onset (V] <sub>σ</sub> N → V] <sub>σ</sub> DN)
<i>Variability?</i>	None mentioned
<i>Contextual restrictions on V-Ũ?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, k, ? NASAL: m, n, ŋ

The analysis I assume is based on the presentation of Amarakaeri orthography on Tripp pp. 11–12, as well as generalizations that emerged while looking through the dictionary. The description of shielding is from the orthography. The claim that oral allophones only occur adjacent to oral vowels is based on an examination of the dictionary. And while Tripp treats nasal and oral allophones as separate phonemes, I found no evidence to support this claim.

Regarding shielding: different places of articulation are differently affected. For labials, /m/ → [mb] preceding oral vowels. For alveolars, /n/ → [nd] preceding oral vowels; /n/ → [dn] following oral vowels. The status of velar consonants is unclear; they may be derived from alveolars.

#### #5: Amundava (Tupí; Sampaio 1998)

<i>Shielding contexts</i>	Prevocalic (NV → NDV) Coda (VN] <sub>σ</sub> → VDN] <sub>σ</sub> )
<i>Variability?</i>	Yes
<i>Contextual restrictions on V-Ũ?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, tʃ, k, k <sup>w</sup> , ? NASAL: m, n, ɲ, ŋ, ŋ <sup>w</sup>

Regarding shielding: the distribution of allophones is to some extent dependent on place of articulation. For labials and alveolars, we find: variation between D, N, and ND in initial position (preceding an oral vowel); ND between nasal and oral vowels, and variation between N and DN (following an oral vowel) word-finally. Velars have no pre-oralized allophone (\*gŋ), but otherwise their distribution is the same.

Vowel nasality contrasts may be neutralized preceding nasal consonants: oral vowels do not appear to be able to precede either nasal or postoralized stops (see p. 44).

#### #6: Andoke (Isolate; Landaburu 2000a)

<i>Shielding contexts</i>	Prevocalic (NV → DV)									
<i>Variability?</i>	None discussed									
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious									
<i>Oral vowel inventory</i>	<table><tr><td>ĩ</td><td>u</td><td>u</td></tr><tr><td>e</td><td>ɣ</td><td>o</td></tr><tr><td>a</td><td>ʌ</td><td>ɒ</td></tr></table>	ĩ	u	u	e	ɣ	o	a	ʌ	ɒ
ĩ	u	u								
e	ɣ	o								
a	ʌ	ɒ								
<i>Nasal vowel inventory</i>	<table><tr><td>ĩ</td><td></td><td></td></tr><tr><td>ẽ</td><td>ɣ̃</td><td>õ</td></tr><tr><td>ã</td><td></td><td>õ̃</td></tr></table>	ĩ			ẽ	ɣ̃	õ	ã		õ̃
ĩ										
ẽ	ɣ̃	õ								
ã		õ̃								
<i>Stop inventory</i>	VOICELESS: p, t, k VOICED/NASAL: M, N, J									

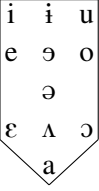
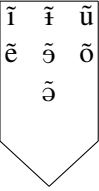
In Landaburu's description, the nasal consonants are treated as allophones of an underlying oral series. As there is no other evidence for nasal spreading, however, an analysis under which the oral allophones are derived from underlying nasal phonemes is equally appropriate, and indistinguishable from Landaburu's given the available data.

#### #7: Apiaká (Tupí; Padua 2007)

<i>Shielding contexts</i>	Prevocalic (NV → NDV, DV)
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V–<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, k, ʔ NASAL: m, n, ŋ

Regarding shielding: the distribution of allophones depends on place of articulation (p. 29). For labials, we find: [b] initially, [mb] in stressed oral syllables, and [m] elsewhere. Alveolars pattern like labials, with the exception that [nd] can also appear before stressed syllables. For velars, we find: [ŋg] in stressed oral syllables (when following a nasal vowel), [g] initially and between post-stress oral vowels, and [ŋ] elsewhere.

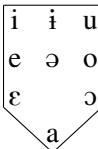
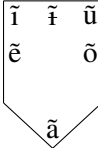
### #8: Apinayé (Macro-Ge; Oliveira 2005)

<i>Shielding contexts</i>	Coda (VN] <sub>σ</sub> → VD] <sub>σ</sub> )
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, tʃ, k, ʔ PRENASAL: mb, nd, ɲdʒ NASAL: m, n, ɲ, ŋ

Apinayé is unique in the shielding typology in that NDs are granted phonemic status (there are a limited number of N vs. ND minimal pairs; see Oliveira pp. 39ff for examples). But the distribution of NDs is restricted: they can only appear in stressed syllable onsets before oral vowels (whereas Ns and Ts can appear in all onsets and codas). Shielding is fairly limited in this system: bilabial /m/ may be realized as [b] word-finally, following non-front mid oral vowels. (Note however that Ham's 1961 analysis treats NDs as allophones of Ns, despite the presence of several minimal pairs; under this analysis there is less neutralization, and much more shielding, going on.)

Regarding the distribution of nasal vowels: contrasts in vocalic nasality are neutralized after nasal consonants.

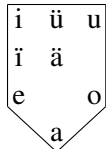
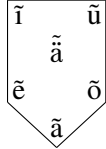
### #9: Arára do Mato Grosso (Isolate; da Rocha D'Angelis 2010)

<i>Shielding contexts</i>	Prevocalic (NV → NDV, DV) Coda (VN] <sub>σ</sub> → VDN] <sub>σ</sub> )
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, tʃ, k NASAL: m, n, ɲ, ŋ

Regarding the phoneme inventory: da Rocha D'Angelis presents two hypotheses about the phonemic inventory (p. 3); here I (arbitrarily) follow the first.

Regarding shielding: in between two oral vowels, Ds are the preferred oral allophones. Word-initially, Ds and NDs are in free variation. There are several exceptional forms in which an oral (or postoralized) consonant precedes a nasal vowel (see da Rocha D'Angelis p. 3).

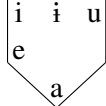
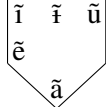
#### #10: Arikapú (Isolate; Arikapú et al. 2010)

<i>Shielding contexts</i>	Prevocalic (NV → NDV, DV)
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, k, ? NASAL: m, n

Regarding shielding: its presence is not discussed, but can be inferred from a look through the lexicon: for example, all <b>s are followed by oral vowels and all <m>s are followed by nasal vowels. The oral allophones of Ns are generally realized as NDs (p. 3):

“...a ortografia prática empregada neste vocabulário inclui alguns símbolos que não refletem um contraste fonológico, mas que têm um valor alofônico: b (alofone do m, geralmente pronunciado como [mb]) e d e dj (ambos alofone do n, geralmente pronunciado como [nd] and [ndj] respectivamente).”

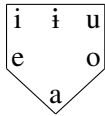
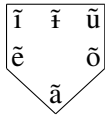
#### #11: Asurini do Xingú (Tupí; Pereira 2009)

<i>Shielding contexts</i>	Prevocalic (NV → NDV, DV)
<i>Variability?</i>	Yes
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, tʃ, k, ? VOICED: dʒ NASAL: m, n, ŋ

Regarding the inventory: it's unclear if what I claim are affricates are really underlyingly affricates, or rather the fricatives they're in free variation with ([ʃ] and [ʒ]).

Regarding shielding: Ns are realized as NDs between nasal and oral vowels. Ns are realized as Ds in all other contexts preceding oral vowels. See Pereira p. 71 for a summary of the distribution.

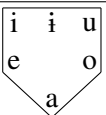
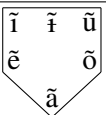
#### #12: Avá-Canoeiro (Tupí; Borges 2006)

<i>Shielding contexts</i>	Prevocalic (NV → NDV, DV)
<i>Variability?</i>	Yes
<i>Contextual restrictions on V-Ũ?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, k, k <sup>w</sup> NASAL: m, n, ŋ

Shielding occurs variably in all oral contexts. The frequency of shielding appears to be, to some extent, dialect-dependent; the Goiás dialect does not have shielding at all (Borges p. 84). Shielding that results in plain oral consonants is only attested in the Estado do Tocantins dialect (see p. 84).

Regarding the distribution of vowel nasality: regressive nasalization (i.e. neutralization of vowel nasality contrasts) is discussed on Borges pp. 90-91.

#### #13: Barí (Chibchan; Mogollón 2000)

<i>Shielding contexts</i>	Prevocalic (NV → NDV)
<i>Variability?</i>	Yes
<i>Contextual restrictions on V-Ũ?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: t, k VOICED: b, d NASAL: m, n, ɲ

Regarding shielding, Mogollón writes (p. 720):

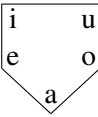
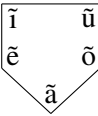
“El fonema /m/ tiene dos alófonos: [m] y [~b]. Se realiza nasal, labial [m], en posición inicial de palabra precediendo a una vocal nasal y en posición intervocálica, en contextos nasales. En posición inicial de palabra, cuando la vocal es oral varía libre-



*mente con el fono oclusivo, labial, prenasal [~b], excepto en palabras monosilábicas, en éstas solo se da [~b].”*

Other places of articulation do not have this word-initial restriction; they differ from the labials in other non-crucial ways. Globally, voiced stops phonemically contrast with nasal stops. Voiced stops occur before oral or nasal vowels, and are prenasalized (as are all other obstruents) when they follow a nasal vowel.

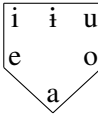
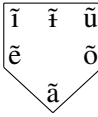
#### #14: Chimila (Chibchan; Malone 2006, 2010)

<i>Shielding contexts</i>	Prevocalic (NV → NDV)
<i>Variability?</i>	Yes
<i>Contextual restrictions on V–Ṽ?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, k, ʔ VOICED: b, d, g NASAL: m, n, ŋ

The inventory assumed here is from Malone (2006). Malone (2006) and Malone (2010) make different claims about whether or not vocalic nasality is contrastive; in this chapter I have followed Malone’s (2006) claim that it is.

Malone (2010) claims that vocalic nasality is contrastive only in onomatopoetic forms and interjections. Nasal vowels are attested elsewhere in the lexicon, but only in underlying forms. He speculates that the shielding observed in the language can be traced to an earlier stage of the language in which nasality was contrastive (p. 10). I am unsure what to make of this claim – if underlyingly nasal vowels never surface as nasal, how does Malone (2006) know which underlying vowels to transcribe as nasal and which to transcribe as oral?

#### #15: Chiriguano, Chané (Tupí; Dietrich 1986)

<i>Shielding contexts</i>	Prevocalic (NV → NDV)
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V–Ṽ?</i>	Probably not
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, k, k <sup>w</sup> , ʔ NASAL: m, n, ŋ

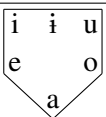
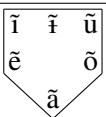
Regarding the distribution of nasal vowels: Dietrich claims that vocalic nasality is only contrastive in stressed syllables (though nasal vowels are transcribed elsewhere), but then notes (p. 94) that the presence vs. absence of shielding in final position reveals to the listener the oral vs. nasal status of the final vowel, which is otherwise hard to determine.

*“A pesar de neutralizarse la oposición oral/nasal de las vocales en posición final y a pesar de realizarse en la norma la correspondiente cualidad archifonemática oral, siempre es posible, en caso que se hallen consonantes nasalizables en sílaba final, averiguar si tal sílaba es fonológicamente oral o nasal”*

This leads me to think that nasality is contrastive outside of stressed syllables, but that the contrast is just more difficult to hear. (There is also long-distance nasal harmony; this is described as a separate phenomenon; see Dietrich pp. 63–64).

Beyond shielding, there are additional restrictions on the distribution of NCs: even if all vowels are oral, two NCs are not allowed to co-occur across a single vowel (Dietrich p. 63).

#### #16: Chiriguano, Izoceño (Tupí; Dietrich 1986)

<i>Shielding contexts</i>	Prevocalic (NV → NDV)
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V–Ṽ?</i>	Probably not
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, k, k <sup>w</sup> , ? VOICED: g <sup>w</sup> NASAL: m, n, ŋ

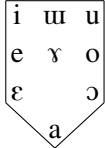
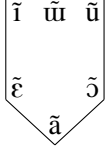
Regarding the distribution of nasal vowels: Dietrich claims that vocalic nasality is only contrastive in stressed syllables (though nasal vowels are transcribed elsewhere), but then notes (p. 94) that the presence vs. absence of shielding in final position reveals to the listener the oral vs. nasal status of the final vowel, which is otherwise hard to determine.

*“A pesar de neutralizarse la oposición oral/nasal de las vocales en posición final y a pesar de realizarse en la norma la correspondiente cualidad archifonemática oral, siempre es posible, en caso que se hallen consonantes nasalizables en sílaba final, averiguar si tal sílaba es fonológicamente oral o nasal”*

This leads me to think that nasality is contrastive outside of stressed syllables, but that the contrast is just more difficult to hear. (There is also long-distance nasal harmony; this is described as a separate phenomenon; see Dietrich pp. 63–64).

Beyond shielding, there are additional restrictions on the distribution of NCs: even if all vowels are oral, two NCs are not allowed to co-occur across a single vowel (Dietrich p. 63).

**#17: Dâw (Nadahup; Martins 2004)**

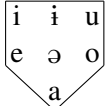
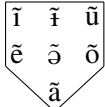
<i>Shielding contexts</i>	Coda (VN] <sub>σ</sub> → VDN] <sub>σ</sub> )
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, c, k, ʔ VOICED: b, d, ɟ, g NASAL: m, n, ɲ, ŋ GLOTTALIZED NASAL: mʔ, nʔ, ɲʔ

Regarding the distribution of shielding: it applies to glottalized and non-glottalized coda nasals alike, in syllables with both short and long vowels.

Regarding the distribution of vocalic nasality, it's explicitly noted that oral and nasal vowels contrast in stressed and stressless syllables alike (p. 62):

*“Todas as vogais orais e nasais ocorrem em sílabas átonas e tônicas.”*

**#18: Epena (Choco; Harms 1984)**

<i>Shielding contexts</i>	Prevocalic (NV → NDV, DV)
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VL. ASPIRATED: p <sup>h</sup> , t <sup>h</sup> , k <sup>h</sup> VOICELESS: p, t, tʃ, k, ʔ NASAL/VOICED: m/b/mb, n/d/nd, g/ŋg

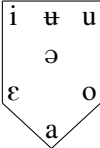
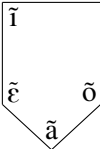
Regarding shielding: the postoralized allophone occurs between a nasal and an oral vowel; if the preceding vowel is not nasal, then the fully oral allophone occurs. The nasal allophone occurs preceding a nasal vowel. Harms does not claim that [g] has a fully nasal allophone; however, all examples of [g] and [ŋg] appear to precede an oral vowel: I was unable to find any forms in which [g] precedes a nasal vowel.

**#19: Hup (Nadahup; Epps 2008)**

<i>Shielding contexts</i>	Prevocalic (NV → NDV) Coda (VN] <sub>σ</sub> → VDN] <sub>σ</sub> Onset (V] <sub>σ</sub> N → V] <sub>σ</sub> D, V] <sub>σ</sub> DND)									
<i>Variability?</i>	None mentioned									
<i>Contextual restrictions on V–<math>\tilde{V}</math>?</i>	None obvious									
<i>Oral vowel inventory</i>	<table border="1"> <tr><td>ĩ</td><td>ï</td><td>u</td></tr> <tr><td>e</td><td>ə</td><td>o</td></tr> <tr><td>æ</td><td>a</td><td>ɔ</td></tr> </table>	ĩ	ï	u	e	ə	o	æ	a	ɔ
ĩ	ï	u								
e	ə	o								
æ	a	ɔ								
<i>Nasal vowel inventory</i>	<table border="1"> <tr><td>ĩ</td><td>ĩ̃</td><td>ũ</td></tr> <tr><td>ẽ</td><td>ã</td><td>õ</td></tr> </table>	ĩ	ĩ̃	ũ	ẽ	ã	õ			
ĩ	ĩ̃	ũ								
ẽ	ã	õ								
<i>Stop inventory</i>	VOICELESS: p, t, c, k, ʔ NASAL: m, n, ɲ, ŋ GLOTTALIZED: b', d', j', g'									

Morphemes are generally monosyllabic; shielding occurs in both onset ([<sup>n</sup>dû:] ‘grandchild’, p. 54) and coda ([tôd<sup>n</sup>] ‘hollow log’, p. 55). In VN-V contexts, N can be realized as D or DND, with specific details of realization to some extent dependent on place of articulation (Epps p. 54–60). (It’s unclear whether or not intervocalic shielding would occur in monomorphemic words, as I have not been able to find any relevant disyllabic words.) Epps does not take a stance on whether the oral or nasal allophones are underlying, but the available data are fully consistent with a shielding analysis, i.e. with an analysis under which the nasal allophones are underlying.

**#20: Jabutí (Macro-Ge; Ribeiro & van der Voort 2010)**

<i>Shielding contexts</i>	Prevocalic (NV → DV)
<i>Variability?</i>	Yes
<i>Contextual restrictions on V–<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	 <p>A trapezoidal diagram representing the oral vowel space. The top row contains the vowels /i/ (left), /ɯ/ (center), and /u/ (right). The middle row contains the central vowel /ə/. The bottom row contains /ɛ/ (left) and /o/ (right). The bottom vertex of the trapezoid contains the low central vowel /a/.</p>
<i>Nasal vowel inventory</i>	 <p>A trapezoidal diagram representing the nasal vowel space. The top vertex contains the nasalized high front vowel /ĩ/. The bottom row contains /ẽ/ (left) and /õ/ (right). The bottom vertex contains the nasalized low central vowel /ã/.</p>
<i>Stop inventory</i>	VOICELESS: p, ps, t, tʃ, k VOICED: bz, dʒ NASAL: m, n

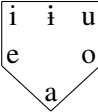
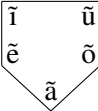
Ribeiro & van der Voort provide the following description of shielding (p. 532):

“...we assume that the language...does not have a set of voiced plosive consonant phonemes that are distinct from nasal consonants. The distribution of [b] and [d] versus [m] and [n] appears to be largely complementary, [b] and [d] occurring basically

only before oral vowels, and [m] and [n] before either nasal or oral vowels.”

The one N vs. D minimal pair that has been cited involves a loanword (fn. 12, p. 532).

**#21: Júma (Tupí; Abrahamson & Abrahamson 1984)**

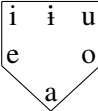
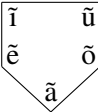
<i>Shielding contexts</i>	Prevocalic (NV → NDV) Coda (VN] <sub>σ</sub> → VDN] <sub>σ</sub> )
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, k VOICED: g NASAL: m, n, ɲ, ŋ

Regarding the distribution of oral allophones: Ns are realized as NDs before oral vowels. Ns are realized as DN word-finally (which is the only place codas are allowed), following oral vowels.

Regarding the distribution of vocalic nasality: it's not clear that oral and nasal vowels contrast before nasals (NDs or Ns). This isn't explicitly discussed, however, and the authors only state that oral vowels in nasal contexts are lightly nasalized (p. 10):

*“Pode-se prever uma ligiera nasalização de qualquer vogal que for seguida de uma nasal, ou de uma variante pré-nasalizada de uma consoante nasal, como por exemplo: m, n, n [ŋ?], mb, nd, ŋg.”*

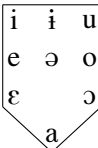
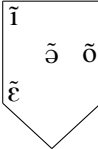
**#22: Kaapor (Tupí; Garcia Lopes 2009)**

<i>Shielding contexts</i>	Prevocalic (NV → NDV)
<i>Variability?</i>	Yes
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	Probably
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, k, k <sup>w</sup> NASAL: m, n, ɲ, ŋ <sup>w</sup>

Regarding the distribution of shielding: only the labial /m/ and alveolar /n/ have oral allophones. The fact that /n/ has oral allophones isn't described on Garcia Lopes's p. 48, but can be inferred from the table of phones on p. 45, where an [nd] allophone is listed.

Regarding the distribution of vocalic nasality: while Garcia Lopes does not discuss this, the vocalic nasality contrast appears to be limited to stressed, word-final position... and in all examples provided to illustrate shielding, shielding occurs word-finally. In other words: the distribution of shielding appears to track restrictions on the distribution of vocalic nasality contrasts.

**#23: Kaingang, São Paulo (Macro-Ge; Cavalcante 1987)**

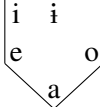
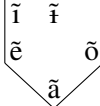
<i>Shielding contexts</i>	Prevocalic (NV → NDV) Coda (VN] <sub>σ</sub> → VDN] <sub>σ</sub> ) Onset (V] <sub>σ</sub> → V] <sub>σ</sub> DN)
<i>Variability?</i>	Yes
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, č, k NASAL: m, n, ɲ, ŋ

Cavalcante (p. 18) describes shielding as a process in which an oral or a nasal consonant is optionally inserted in between a nasal consonant and an oral vowel.

*“(insere-se opcionalmente uma consoante não nasal homorgânica vozeada entre uma vogal oral e uma consoante nasal, e vice-versa, ou seja, insere-se uma consoante nasal homorgâmica vozeada entre uma consoante nasal e uma vogal oral).”*

The distribution of allophones can be characterized as follows: N → DN, NN / V\_  $\tilde{V}$  (across word boundaries, NN is the only available allophone); N → ND, NN / \_ V; N → N / elsewhere.

**#24: Kakua (Kakua-Nukak; Cathcart 1979)**

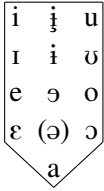
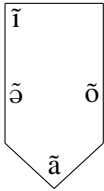
<i>Shielding contexts</i>	Prevocalic (NV → NDV, DV) Coda (VN] <sub>σ</sub> → VDN] <sub>σ</sub> )
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, k VOICED/NASAL: b/m, d/n, g/ŋ

In initial position, Ns are realized as NDs before oral vowels. Ns are realized as DNs in coda position, following oral vowels. Ns are realized as Ns in all other contexts. Cathcart treats the oral allophones of Ns as the underlying phonemes, but recognizes that this choice is arbitrary (from Cathcart p. 11):

*“La serie nasal podría haberse utilizado como fonema. Se optó por la serie oral debido a la facilidad de representarse.”*

With regards to the status of contrastive nasality: vocalic nasality is treated as a suprasegmental property (p. 23), but the data presented are equally compatible with an analysis in which vowels phonemically contrast for nasality.

#### #25: Karajá (Macro-Ge; Ribeiro 2012)

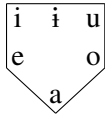
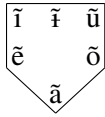
<i>Shielding contexts</i>	Prevocalic (NV → DV)
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: (tʃ), k VOICED/NASAL: b/m, d/n, (dʒ) IMPLOSIVE: ɖ

Regarding the phonemic inventory: above, consonantal phonemes in parentheses are not independent phonemes, but derived through consonant palatalization preceding high vowels. Phonemic status of schwa is “problematic” (Ribeiro 2012:87).

Regarding shielding: nasal /m/ and /n/ are in complementary distribution with oral /b/ and /d/ (Ribeiro pp. 83–84, see quote below). Shielding occurs before all vowels but /a/.

*“...in Karajá the voiced stops /b/ and /d/ do not contrast phonologically with their nasal counterparts. They are pronounced as fully oral consonants before oral vowels and fully nasal consonants before nasal vowels [... ]”*

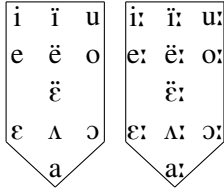
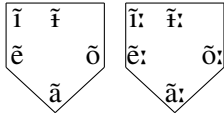
**#26: Karapanã (Tucanoan; Metzger & Metzger 1973)**

<i>Shielding contexts</i>	Prevocalic (NV → NDV, DV)
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, k NASAL: m, n, ŋ

Regarding shielding: Ns are realized variably as Ds or NDs before oral vowels and word-initially. Between oral vowels, Ns are realized as Ds; between a nasal and an oral vowel, Ns are realized as NDs. Metzger & Metzger treat the oral allophones of the nasal phonemes as basic. The oral and nasal allophones are in complementary distribution, however, so the nasal allophones could just as well be basic.

Regarding other phenomena involving nasality: it's mentioned at the end of the description (Metzger & Metzger p. 131) that nasal harmony is present, but it's not clear how extensive this process is, i.e. whether or not the shielding facts can be explained as a consequence of harmony.

**#27: Karitiãna (Tupí; Storto 1999, Everett 2007)**

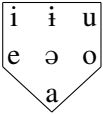
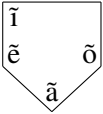
<i>Shielding contexts</i>	Prevocalic (NV → NDV) Coda (VN] <sub>σ</sub> → VDN] <sub>σ</sub> ) Onset (V] <sub>σ</sub> → V] <sub>σ</sub> DN)
<i>Variability?</i>	Yes
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, k NASAL: m, n, ñ, ŋ

The distribution of allophones, according to Storto (1999:25ff), is: N → ND /  $\tilde{V}$ \_ V, #\_ V (older speakers only); N → DN / V\_ $\tilde{V}$ , V\_#; N → D / #\_ V (younger speakers only); N → DND / V\_V; N → N / elsewhere. Storto (1999) notes that the palatal nasal lenites intervocalically (p. 27). She also notes (p. 30) that the presence of medionasals is somewhat speaker-dependent (see also Everett 2007): others pronounce them as NDs or plain Ds. When pronounced as NDs, the previous vowel



is nasalized (it's not clear whether or not contrasts in vocalic nasality are neutralized).

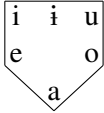
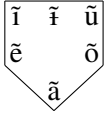
**#28: Karo (Tupí; Gabas 1998)**

<i>Shielding contexts</i>	Prevocalic (NV → NDV) Coda (VN] <sub>σ</sub> → VDN] <sub>σ</sub> )
<i>Variability?</i>	None mentioned
<i>Contextual restrictions on V–Ṽ?</i>	Probably
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, c, k, ? VOICED: b, g NASAL: m, n, ŋ

Shielding is contextually restricted: it occurs only in stressed syllables. This restriction on shielding appear to track a restriction on the distribution of vocalic nasality contrasts. Throughout the description it is apparent that nasal vowels occur predominantly in stressed position (though there are several exceptions; see e.g. Gabas p. 57 for a form with nasality outside of stressed position).

Regarding other phenomena involving nasality: nasality optionally spreads regressively from onset nasals (see Gabas pp. 63–64).

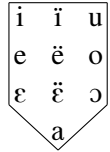
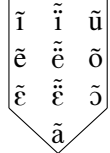
**#29: Kotiria (Tucanoan; Waltz & Waltz 1972)**

<i>Shielding contexts</i>	Prevocalic (NV → DV)
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V–Ṽ?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VL. ASPIRATED: p, t, k VL. UNASPIRATED: p <sup>h</sup> , t <sup>h</sup> , k <sup>h</sup> VOICED/NASAL: b/m, d/n, g/ŋ

Regarding shielding: Ns are only realized as Ds when both surrounding vowels are oral; /wāhãŋa/, for example, is realized as [wāhãŋa]. Waltz & Waltz treat the oral allophones of the nasal phonemes as basic. The oral and nasal allophones are in complementary distribution, however, so the nasal allophones could just as well be basic.

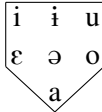
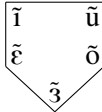
“...completa simetría dentro de las oclusivas y continuas con sus variantes nasales.”

**#30: Krahô (Macro-Ge; Popjes & Popjes 2009)**

<i>Shielding contexts</i>	Coda (VN] <sub>σ</sub> → VDN] <sub>σ</sub> )
<i>Variability?</i>	None mentioned
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, k NASAL: m, n, ŋ

A few details about shielding: the only restriction on the distribution of DN's noted by Popjes & Popjes is that they “occur only following an oral vowel” (p. 9). In all examples provided, however, shielding only occurs in coda position. Velar /ŋ/ also varies allophonically with /ŋg/ and /g/, but this doesn't appear to be an instance of shielding as this variation takes place before both oral and nasal vowels.

**#31: Krenak (Macro-Ge; Pessoa 2012)**

<i>Shielding contexts</i>	Prevocalic (NV → NDV) Coda (VN] <sub>σ</sub> → VDN] <sub>σ</sub> ) Onset (V] <sub>σ</sub> N → V] <sub>σ</sub> DN)
<i>Variability?</i>	Yes
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, tʃ, k, ʔ VD. NASAL: m, n, ɲ, ŋ VL. NASAL: ɱ, ɳ, ɲ̃, ɳ̃

Shielding is generally more frequent in stressless syllables (quote from Pessoa p. 113):

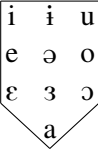
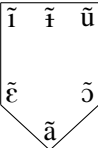
*“Isto [shielding] ocorre com menos frequência, muitas vezes em sílabas não acentuadas, mas também ocorrem em sílabas acentuadas.”*

But shielding in coda, following oral vowels, occurs more often in stressed (final) syllables (p. 122):

“...tais segmentos tendem a ocorrer em meio ou final de palavra, geralmente em sílabas acentuadas. Sua realização está também relacionada à presença obrigatória de vogais orais como núcleo da sílaba.”

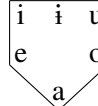
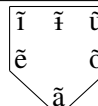
A few more details: in prevocalic position, NDs cannot precede /ɛ/ and Ns cannot precede /ɔ/. In a VN]<sub>σ</sub> context, when shielding fails to apply, the vowel is nasalized (see Pessoa pp. 176ff).

### #32: Krinkati-Timbira (Macro-Ge; Alves 2004)

<i>Shielding contexts</i>	Prevocalic (NV → NTV) Coda (VN] <sub>σ</sub> → VDN] <sub>σ</sub> )
<i>Variability?</i>	Yes
<i>Contextual restrictions on V–Ṽ?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, tʃ, k, NASAL: m, n, ɲ, ŋ

Shielding in the NV context is restricted to morpheme-initial position. (For discussion of other restrictions on the distribution of the NT allophones, see p. 33.) In addition, shielding in coda position isn’t explicitly discussed as such; see Alves pp. 34ff. Shielding in coda only variably occurs, and when it fails, the preceding vowel is nasalized.

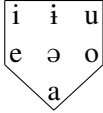
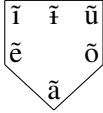
### #33: Kubeo (Tucanoan; Chacon 2012)

<i>Shielding contexts</i>	Prevocalic (NV → DV)
<i>Variability?</i>	None mentioned
<i>Contextual restrictions on V–Ṽ?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, tʃ, k VOICED/NASAL: b/m, d/n

The descriptive facts: the voiced consonant series is oral (e.g. D) before an oral vowel and nasal (e.g. N) before a nasal vowel. Chacon treats nasality as a “feature of the entire syllable” (p. 82–83), but I believe the data are equally compatible with an analysis under which vocalic nasality is contrastive and shielding occurs to enhance the vocalic contrast.

Progressive nasal harmony applies across morpheme boundaries; see Chacon p. 86ff for details.

**#34: Mako (Salivan; Labrada 2015)**

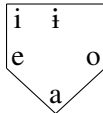
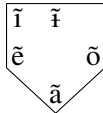
<i>Shielding contexts</i>	Prevocalic (NV → DV)
<i>Variability?</i>	None mentioned
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	ASPIRATED: p <sup>h</sup> , t <sup>h</sup> VOICELESS: p, t, k, k <sup>w</sup> , ʔ VOICED: b, d NASAL: m, n PREGLOTTALIZED: ʔb/ʔm, ʔd/ʔn, ʔdʒ/ʔɲ

Regarding the distribution of preglottalized stops, Rosés Labrada writes the following:

*“Available evidence suggests (see all the contexts above, for instance) that the pre-glottalized nasals only occur when the following vowel is a nasal and the pre-glottalized oral stops when the following vowel is oral. This complementary distribution allows me to affirm that the pre-glottalized nasals are allophonic variants of the other three pre-glottalized consonants.”*

But the available evidence is equally compatible with an analysis under which the nasal preglottalized consonants are phonemic, and the oral allophones occur adjacent to oral vowels.

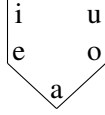
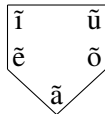
**#35: Makuráp (Tupí; Braga 1992)**

<i>Shielding contexts</i>	Prevocalic (NV → NDV, DV)
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, tʃ, k, NASAL: m, n, ɲ, ŋ

A note regarding the inventory: It appears that vowels also contrast for length, though this is not explicitly discussed; see Braga pp. 57ff.

Regarding shielding: NDs and Ds are in free variation in initial position, before oral vowels. Ds also occur in stressed oral syllables. Ns generally occur in stressless syllables, but /ŋ/ has an oral allophone [g] that can occur in any prosodic context, between two oral vowels, and /ɲ/ has continuant allophones in this same position. (Note that what I analyze as /ɲ/ is analyzed by Braga as underlying /j/; however, its allophones are in complementary distribution and it behaves very similarly to the other nasal phonemes.)

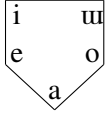
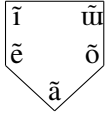
**#36: Mamaindé (Nambiquaran; Eberhard 2009)**

<i>Shielding contexts</i>	Coda (VN] <sub>σ</sub> → VDN] <sub>σ</sub> )
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	 <p>DIPHTHONGS: iu, ei, eu, ai, au</p>
<i>Nasal vowel inventory</i>	 <p>DIPHTHONGS: ãũ, ẽĩ, ẽũ, ăĩ, ăũ</p>
<i>Stop inventory</i>	<p>VL. UNASPIRATED: p, t, k, ʔ</p> <p>VL. ASPIRATED: p<sup>h</sup>, t<sup>h</sup>, k<sup>h</sup></p> <p>NASAL: m, n</p>

Nasal place contrasts are neutralized in coda position. The realization of the preoralized variant depends on the vowel that precedes it. Generally speaking, the distribution is as follows: [b<sup>m</sup>] after oral diphthongs with round vowels (/au/, /eu/); [ɣ<sup>n</sup>] after the high front vowel (/i/); and [d<sup>n</sup>] after all of the oral vowels not listed above. (For discussion of some exceptions, see Eberhard p. 91.)

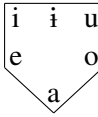
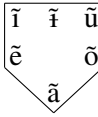
Mamaindé also has a set of contrastively laryngealized vowels, and a set of contrastively laryngealized and nasalized vowels; see Eberhard pp. 98ff for the simple vowels and p. 118ff for the diphthongs. These are however being lost in younger generations.

**#37: Maxakalí (Macro-Ge; Campos 2009)**

<i>Shielding contexts</i>	Prevocalic (NV → NDV, DV)
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	<p>VOICELESS: p, t, c, k, ʔ</p> <p>NASAL: m, n, ɲ, ŋ</p>

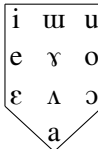
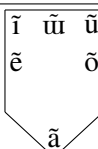
It appears that ND and D are in free variation preceding oral vowels (see Campos p. 18).

**#38: Mbyá (Tupí; Martins 2003, Thomas 2014)**

<i>Shielding contexts</i>	Prevocalic (NV → NDV)
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, tʃ, k, k <sup>w</sup> , ʔ NASAL: m, n, ɲ, ɲ <sup>w</sup>

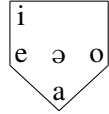
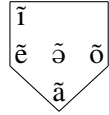
The inventory provided above is a synthesis of information provided by two sources, Martins (2003) and Thomas (2014). Mbyá also has long-distance nasal harmony, but Thomas analyzes long-distance harmony as a process entirely separate from syllable-internal nasal agreement (i.e. shielding).

**#39: Mebengokre (Macro-Ge; Salanova & Silva 2011)**

<i>Shielding contexts</i>	Coda (VN] <sub>σ</sub> → VDN] <sub>σ</sub> )
<i>Variability?</i>	None mentioned
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, tʃ, k, ʔ VOICED: b, d, dʒ, g NASAL: m, n, ɲ, ɲ

Morpheme-final stops assimilate to the [±nasal] value of a following onset consonant; see Salanova & Silva p. 1532 for discussion.

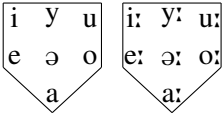
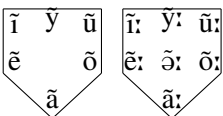
#### #40: Mundurukú (Tupí; Picanço 2005)

<i>Shielding contexts</i>	Coda (VN] <sub>σ</sub> → VDN] <sub>σ</sub> )
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V–Ṽ?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, tʃ, k VOICED: b, d, dʒ NASAL: m, n, ŋ

Regarding shielding: Picanço (p. 26, 76ff) claims that the desire to preserve a contrast is what leads to shielding: “... preoralization is a strategy used by speakers to preserve a phonological contrast.” Picanço also notes that the distribution of shielding parallels the distribution of vocalic nasality contrasts. It’s not clear, however, that this is significant: vocalic nasality is only contrastive at the morpheme’s right edge, and nasals can only appear in coda position word-finally. See fn. 3 on Picanço’s p. 77.

Other potentially relevant facts: Mundurukú has a series of contrastively laryngealized (and contrastively laryngealized + creaky) vowels; see Picanço pp. 34ff. Mundurukú also has nasal harmony; see Chapter 6 of Picanço (2005).

#### #41: Myky (Isolate; Montserrat 2010)

<i>Shielding contexts</i>	Prevocalic (NV → NDV)
<i>Variability?</i>	Yes
<i>Contextual restrictions on V–Ṽ?</i>	Probably
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, k, ʔ VL. PALATALIZED: pʲ, tʲ, kʲ NASAL: m, n NAS. PALATALIZED: mʲ, nʲ

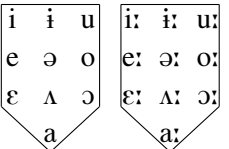
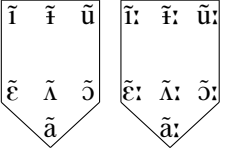
Only a few speakers exhibit shielding. Montserrat’s description (p. 1):

*“Alguns poucos falantes (em geral iranxe, e dois ou três myky) realizam m em posição inicial como [mb]: muhu [mbuhu] ‘chuva’ [...]”*

Montserrat does not state that shielding only occurs before oral vowels, but in all examples provided, the following vowel is oral.

In final stressless (or non-high-toned) position, vowel nasalization contrasts can be neutralized. Speakers appear to not be able to distinguish oral from nasal vowels in this context. Shielding only occurs word-initially; thus it only occurs in contexts where the vocalic nasality contrast is licensed.

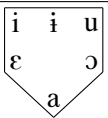
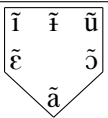
#### #42: Nadêb (Nadahup; Barbosa 2005)

<i>Shielding contexts</i>	Coda (VN] <sub>σ</sub> → VDN] <sub>σ</sub> )
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	Probably
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, k VOICED: b, d, ɟ, g NASAL: m, n, ɲ, ŋ

Shielding in coda position occurs regardless of whether or not the oral vowel has a nasal pair of the same quality (e.g. /wɔja'pəm/ → [wɔja'pə<sup>b</sup>m], p. 44). In addition, nasality appears to only be contrastive in (stressed) final position, which is where shielding occurs. In other words, restrictions on the distribution of shielding appear to track restrictions on the vocalic nasality contrast.

Nadêb also appears to have a series of long laryngealized vowels. See Barbosa pp. 52-53.

#### #43: Nhandeva (Tupí; Costa 2007)

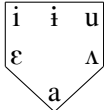
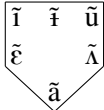
<i>Shielding contexts</i>	Prevocalic (NV → NDV)
<i>Variability?</i>	Yes
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, ts, tʃ, k, k <sup>w</sup> , ʔ VD/NASAL: mb/m, nd/n, dʒ/ɲ, ŋg/ŋ, ŋgw/ŋw

Costa analyzes the prenasalized stop allophones as underlying, but an analysis under which the nasals are underlying is equally consistent with the data.



Regarding vowel nasalization: on Costa's p. 90 there is evidence that when shielding fails to apply, the oral vowel is nasalized. In addition, NDs appear to nasalize vowels that precede them; see p. 96. With respect to the data on p. 96, note that the vowel that gets shielded is always word-final, and nasality is only contrastive word-finally (where there is stress).


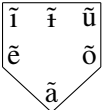
**#44: Nukak (Kakua-Nukak; Mahecha et al. 2000)**

<i>Shielding contexts</i>	Prevocalic (NV → DV) Coda (VN] <sub>σ</sub> → VDN] <sub>σ</sub> ) Onset (V] <sub>σ</sub> → VD] <sub>σ</sub> , VDN] <sub>σ</sub> )
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V–Ṽ?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, c, k, ʔ VD/NASAL: B, D, J, G

In Mahecha et al.'s (2000) description, the voiced stops are treated as underlying phonemes and the nasals are treated as derived allophones. As far as I can tell, there's no reason to prefer this analysis over another one, in which the oral allophones are derived from underlying nasal stops (i.e. there is shielding).

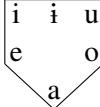
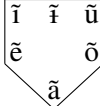
See Mahecha et al. p. 552 for a discussion of some local nasal harmony: liquids are nasalized when adjacent to a nasal vowel.

**#45: Pai Tavytera (Tupí; Cardoso 2008)**

<i>Shielding contexts</i>	Prevocalic (NV → NDV, DV)
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V–Ṽ?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, k, k <sup>w</sup> NASAL: m, n, ɲ, ɲ <sup>w</sup>

ND and D appear to be in free variation before oral vowels. There is some variation of what allophones are possible according to place of articulation; see Cardoso p. 212 for a summary.

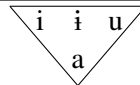
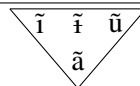
**#46: Piratapuyo (Tucanoan; Klumpp & Klumpp 1973)**

<i>Shielding contexts</i>	Prevocalic (NV → DV)
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, k, ? VOICED/NASAL: b/m, d/n, g/ŋ

Regarding the analysis of consonantal alternations: Klumpp & Klumpp treat the oral allophones of the nasal phonemes as underlying. The oral and nasal allophones are in complete complementary distribution, however, so the alternative analysis is available.

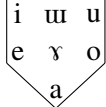
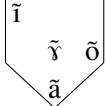
The possibility of nasal harmony is raised on p. 151 (it appears that multiple vowels in a word like to be nasal) but not explored.

**#47: Poyanáwa (Panoan; De Paula 1992)**

<i>Shielding contexts</i>	Prevocalic (NV → DV)
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, k VOICED/NASAL: b/m, d/n

Regarding the analysis of consonantal alternations: De Paula treats the oral allophones as underlying (the rationale is given on pp. 57-58). The oral and nasal allophones are in complete complementary distribution, however, so an analysis where the nasal allophones are underlying seems equally appropriate.

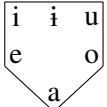
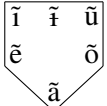
**#48: Puinave (Isolate; Girón 2007)**

<i>Shielding contexts</i>	Prevocalic (NV → DV, NDV)
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, k, ? NASAL: m, n

Whether shielding results in a fully oral or a postoralized consonant depends on the vocalic context: postoralized consonants appear word-initially and in between a nasal + oral vowel, while plain oral consonants appear between two oral vowels.

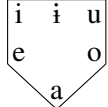
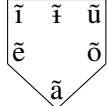
Nasal vowels nasalize preceding and following glides; see Girón pp. 40–41 for discussion.

**#49: Secoya del Aguarico (Tucanoan; Johnson & Levinsohn 1990)**

<i>Shielding contexts</i>	Prevocalic (NV → DV)
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, k, k <sup>w</sup> , ? VOICED/NASAL: m, d/n

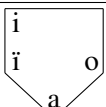
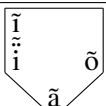
The oral stop [d] is in complementary distribution with nasal [n] (oral [d] appears before oral vowels, and nasal [n] appears before nasal vowels). Johnson & Levinsohn treat the oral allophone as the underlying phoneme, but the nasal allophone could just as well be the underlying phoneme. Note that while there is no oral allophone of [m] recorded, all provided examples of [m] precede a nasal vowel.

**#50: Secoya del Putumayo (Tucanoan; Vallejos 2013)**

<i>Shielding contexts</i>	Prevocalic (NV → DV)
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, k, k <sup>w</sup> , ? VOICED/NASAL: m, d/n, dʒ/ɲ

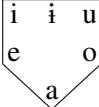
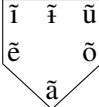
Oral [d] and [dʒ] appear before oral vowels, and nasal [n] and [ɲ] appear before nasal vowels. Vallejos claims that the oral allophones are phonemic, but the data are equally compatible with an analysis under which the nasal allophones are phonemic. In this dialect, shielding appears not to occur for the labial series: [m] is transcribed before both nasal and oral vowels.

**#51: Sharanawa (Panoan; Pike & Scott 1962)**

<i>Shielding contexts</i>	Prevocalic (NV → NDV)
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, ts, tʃ, c, k NASAL: m, n

Glides are nasalized in between nasal vowels (Pike & Scott p. 6).

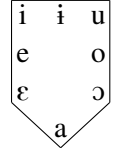
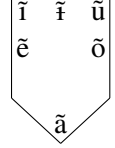
**#52: Sirionó (Tupí; Gasparini 2012)**

<i>Shielding contexts</i>	Prevocalic (NV → NDV)
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: t, k, k <sup>j</sup> NASAL: m, n, ɲ

The distribution of allophones in Sirionó is a bit surprising. For the bilabial and alveolar nasals (the only ones that exhibit shielding), shielding only occurs if the preceding context is a nasal vowel (or a word boundary): N → ND / #\_V,  $\tilde{V}$ \_V, and N → N / #\_V, V\_ $\tilde{V}$ , V\_V. There are also postoralized palatal and velar allophones ([ɲɔ̃] and [ŋg]), but Gasparini analyzes these as allophones of voiceless /tʃ/ and /k/, respectively.

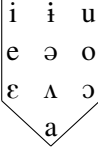
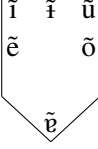
Vowels in Sirionó also appear to contrast for length; see Gasparini pp. 95ff.

**#53: Suyá (Macro-Ge; Guedes 1993)**

<i>Shielding contexts</i>	Prevocalic (NV → NDV, DV)
<i>Variability?</i>	Yes
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, č, k NASAL: m, n, ñ, ɲ

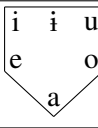
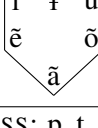
The bilabial and alveolar postoralized stops appear to be in free variation with nasal stops in all vocalic contexts (see Guedes pp. 52ff for discussion). The velar postoralized allophones only seem to appear preceding oral vowels (see p. 53), though there is some variability. The palatal postoralized affricates ([ɲ̃] and [nč]) are treated as allophones of plain affricates. However, they appear to be in complementary distribution with the palatal nasal [ɲ], and [ɲ̃] appears to be in free variation with [j]. Both appear before oral vowels only; [ɲ̃] and its variant [j] can appear word-initially while [nč] cannot. See Guedes p. 54 for more details.

**#54: Tapayuna (Macro-Ge; Camargo 2010)**

<i>Shielding contexts</i>	Prevocalic (NV → NDV)
<i>Variability?</i>	Yes
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: t, t̪, k NASAL: m, n, ɲ, ŋ

Before oral vowels, Ns and NDs are in free variation. All nasals except the palatal nasal exhibit shielding. Shielding is variable for the bilabial and alveolar series, but obligatory for the velar series: [ŋ] and [ŋg] are in complementary distribution.

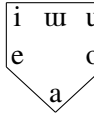

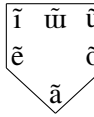

**#55: Tenharim (Tupí; Sampaio 1998)**

<i>Shielding contexts</i>	Prevocalic (NV → NDV)
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, t̪, k, k <sup>w</sup> , ʔ NASAL: m, n, ɲ, ŋ, ŋ <sup>w</sup>

The distribution of oral allophones is to some extent dependent on place of articulation; see Sampaio pp. 21ff.

It's possible that contrasts in vocalic nasality are neutralized in coda position: oral vowels do not appear to be able to precede either nasal or postoralized stops (see Sampaio p. 27 for a summary).

**#56: Ticuna of San Martín de Amacayacu (Isolate; Montes Rodríguez 2005)**

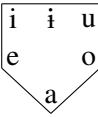
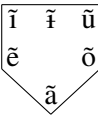
<i>Shielding contexts</i>	Prevocalic (NV → DV)
<i>Variability?</i>	Yes
<i>Contextual restrictions on V–Ṽ?</i>	None obvious
<i>Oral vowel inventory</i>	 
<i>Nasal vowel inventory</i>	 
<i>Stop inventory</i>	VOICELESS: p, t, tʃ, k, kʷ, ? VOICED/NASAL: b/m, d/n, ʃ/ɲ, g/ŋ, gw/ŋw

Regarding shielding: Ns are realized as Ns before nasal vowels, and as Ds before oral vowels. Montes Rodríguez treats the oral allophones as underlying. The oral and nasal allophones are in complete complementary distribution, however, so it is also possible to treat the nasal allophones as underlying.

In some dialects, shielding appears to apply only optionally (see Montes Rodríguez p. 104). The contrast in vocalic nasality also appears to be marginally contrastive in these dialects, but only for /o/ and /a/:

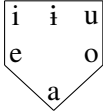
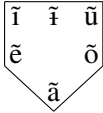
*“Sin embargo esta oposición es incompleta ya que el proceso parece sólo plenamente cumplido con las vocales /o/ y /a/.”*

**#57: Tupinambá (Tupí; Jensen 1984; Moore et al. 1993)**

<i>Shielding contexts</i>	Prevocalic (NV → NDV)
<i>Variability?</i>	Yes
<i>Contextual restrictions on V–Ṽ?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, k, ? VOICED: b NASAL: m, n, ŋ

Shielding is obligatory in stressed syllables, but only optional in unstressed syllables. Nasality may only be contrastive in stressed syllables, as it appears to only be transcribed in that position. This restriction, however, isn't explicitly discussed.

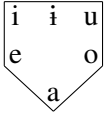
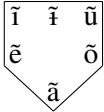
**#58: Uru-Eu-Wau-Wau (Tupí; Sampaio 1998)**

<i>Shielding contexts</i>	Prevocalic (NV → NDV) Coda (VN] <sub>σ</sub> → VDN] <sub>σ</sub> )
<i>Variability?</i>	Yes
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, tʃ, k, k <sup>w</sup> , ʔ NASAL: m, n, ɲ, ŋ, ŋ <sup>w</sup>

The distribution of oral allophones is to some extent dependent on place of articulation. For labials and alveolars, we find variation between Ds, Ns, and NDs in initial position, preceding an oral vowel. Between nasal and oral vowels, we find NDs. Word-finally following an oral vowel, we find variation between Ns and DN. Velars have no pre-oralized allophone (\*[gŋ]), but otherwise their distribution parallels the labials and alveolars.

It appears that all vowels preceding nasal or postoralized stops are nasalized (Sampaio p. 44).

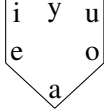
**#59: Waimaha (Tucanoan; Stolte & Stolte 1976)**

<i>Shielding contexts</i>	Prevocalic (NV → NDV, DV)
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, k VOICED/NASAL: b/mb/m, d/nd/n, g/ŋg/ŋ

Ns are realized as NDs between nasal and oral vowels. Ns are realized as Ds word-initially, before oral vowels, and between oral vowels. Barnes & Silzer treats the oral allophones as underlying. The oral and nasal allophones are in complete complementary distribution, however, so it is also possible to treat the nasal allophones as underlying.



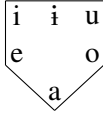
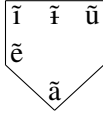
**#60: Wari' (Chapakuran; Everett & Kern 1997)**

<i>Shielding contexts</i>	Prevocalic (NV → NDV)
<i>Variability?</i>	Yes
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	Probably
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	FALLING DIPHTHONGS: $\tilde{e}^i$ , $\tilde{a}^i$ , $\tilde{o}^i$ , $y^i$ RISING DIPHTHONGS: $i^{\tilde{o}}$ , $\tilde{e}^{\tilde{o}}$ , $\tilde{a}^{\tilde{o}}$ , $\tilde{o}^{\tilde{o}}$
<i>Stop inventory</i>	VOICELESS: p, t, tʃ, k, k <sup>w</sup> NASAL: m, mʔ, n, nʔ

/m/ and /n/ are in free variation with postoralized allophones [mb] and [nd]. These allophones appear mainly in stressed syllables and before oral vowels, though there are a couple of examples where this fluctuation precedes a nasal vowel (see e.g. p. 389). The sounds [mʔ] and [nʔ] may be coda allophones of the plain nasals.

The distribution of nasal vowels is also mostly limited to stressed syllables (though see Everett & Kern 1997:396 for an exception), just like the distribution of postoralized allophones.

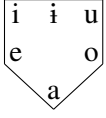
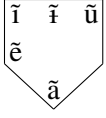
**#61: Wayampi, Alto Jarí (Tupí; Jensen 1984)**

<i>Shielding contexts</i>	Prevocalic (NV → NDV)
<i>Variability?</i>	Yes
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, k, k <sup>w</sup> , ʔ NASAL: m, n, ŋ, ŋ <sup>w</sup>

Shielding is optional in stressed syllables, and does not occur in stressless syllables. Nasality may only be contrastive in stressed syllables, but this is not clear from the description. (Jensen proposes a rule (p. 14) that derives word-final nasal vowels from VN sequences. However, this does not rule out the possibility that nasal vowels exist in other positions. In a small lexicon of Wayampí forms (Jensen pp. 33ff), most transcribed nasal vowels are found in final position... but not all (e.g. [piãpè], p. 36).)

Other potentially relevant facts: contrasts in vocalic nasality appear to be neutralized preceding a coda nasal (see Jensen p. 15).

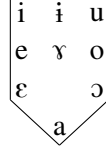
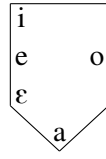
## #62: Wayampi, Ampari (Tupí; Jensen 1984)

<i>Shielding contexts</i>	Prevocalic (NV → NDV)
<i>Variability?</i>	Yes
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, k, k <sup>w</sup> , ? NASAL: m, n, ŋ, ŋ <sup>w</sup>

Shielding is optional in stressed syllables, and does not occur in stressless syllables. Nasality may only be contrastive in stressed syllables, but this is not clear from the description. (Jensen proposes a rule (p. 14) that derives word-final nasal vowels from VN sequences. However, this does not rule out the possibility that nasal vowels exist in other positions. In a small lexicon of Wayampí forms (Jensen pp. 33ff), most transcribed nasal vowels are found in final position. . . but not all (e.g. [piãpè], p. 36).)

Other potentially relevant facts: contrasts in vocalic nasality appear to be neutralized preceding a coda nasal (see Jensen p. 15).

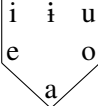
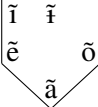
## #63: Xavánte (Macro-Ge; Quintino 2000)

<i>Shielding contexts</i>	Prevocalic (NV → DV)
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, (k) VOICED/NASAL: b/m, d/n

Regarding the inventory: [k] appears to have marginal phonemic status; see Quintino pp. 115ff for discussion. /n/ has nasal allophones [n], [ɲ], and [ŋ]; their distribution is governed by the identity of the following nasal vowel. See Quintino pp. 124ff. There are additional interactions between nasality and laryngealization in Xavánte; see Quintino pp. 123 for illustration and discussion.

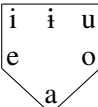
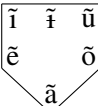
Regarding shielding: Quintino analyzes the voiced stop allophones of the nasals as underlying; it is also possible to analyze the nasal allophones as underlying. In some cases, shielding fails to apply (see Quintino p. 123 for more details).

**#64: Xetá (Tupí; Vasconcelos 2008)**

<i>Shielding contexts</i>	Prevocalic (NV → NDV)
<i>Variability?</i>	Yes
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, tʃ, k, ʔ VOICED: dʒ NASAL: m, n, ŋ

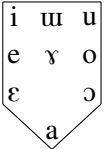
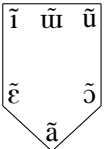
Ns are variably realized as NDs before oral vowels. Vasconcelos explicitly states that vowels contrast for nasality in all positions within the word; see Vasconcelos pp. 47ff for discussion.

**#65: Yagua (Peba-Yaguan; Peña 2009)**

<i>Shielding contexts</i>	Prevocalic (NV → NDV)
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V-<math>\tilde{V}</math>?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, tʃ, k NASAL: m, n

Peña discusses analyses of Yagua presented by Payne & Payne (1990) and Powlison (1995); I have arbitrarily decided to follow his presentation of Payne & Payne. Powlison's analysis differs only in that it posits a smaller vowel inventory, which isn't crucial for the present purposes.

**#66: Yuhup (Nadahup; Martins 2005)**

<i>Shielding contexts</i>	Prevocalic (NV → DV) Coda (VN] <sub>σ</sub> → VDN] <sub>σ</sub> , VD] <sub>σ</sub> ) Onset (V] <sub>σ</sub> → V] <sub>σ</sub> DN)
<i>Variability?</i>	None discussed
<i>Contextual restrictions on V-Ũ?</i>	None obvious
<i>Oral vowel inventory</i>	
<i>Nasal vowel inventory</i>	
<i>Stop inventory</i>	VOICELESS: p, t, c, k, ʔ VOICELESS GLOTTALIZED: cʔ, kʔ VOICED/NASAL: b/bm/m, d/dn/n, ʃ/ʃp/p, ɡ/ɡŋ/ŋ GLOT. VOICED/NAS: bʔ/mʔ, dʔ/nʔ, ʃʔ/pʔ, ɡʔ/ŋʔ

Martins analyzes the oral allophones of the nasal/oral series as underlying. The oral and nasal allophones are in complete complementary distribution, however, so it is also possible that the nasal allophones are underlying.

Note also that the glottalized series does not license partially oral allophones: in coda position following an oral vowel, /mʔ/ is realized as [bʔ]. Martins (p. 83) notes that this is probably because final glottalized segments are not released.

### 3.6.3 List of non-shielding languages

Table 3.3: List of non-shielding languages

No.	V-Ũ? (Evidence)	Language (Family)	Source
Y1	Yes (MP)	Achuar-Shiwiar (Jivaroan)	Fast (1975)
Y2	Yes (MP)	Akuntsu (Tupí)	Aragon (2008)
Y3	Yes (NVNE)	Apalaí (Carib)	Koehn & Koehn (1986)
Y4	Yes (MP)	Apurinã (Arawak)	Facundes (2000)
Y5	Yes (MP)	Araweté (Tupí)	Alves (2008)

No.	V-Ũ?	Language (Family)	Source
Y11	Yes (MP)	Baré (Arawak)	Aikhenvald (1995)
Y12	Yes (NVNE)	Bésiro (Macro-Ge)	Sans (2010)
Y13	Yes (–)	Canela (Macro-Ge)	de Sá Amado & de Carvalho de Souza (2007)
Y14	Yes (MP)	Cashinahua (Panoan)	Kensinger (1963)
Y15	Yes (NVNE)	Cayubaba (Isolate)	Key (1967)
Y16	Yes (–)	Cha'palaa (Barbacoan)	Floyd (2010)
Y17	Yes (NVNE)	Chamacoco (Zamucoan)	Huntington (2012)
Y18	Yes (MP)	Desano (Tucanoan)	Silva (2012)
Y19	Yes (–)	Emberá-Baudó (Choco)	Adelaar & Muysken (2004)
Y20	Yes (MP)	Emberá-Catío (Choco)	Mortensen (1994)
Y21	Yes (NVNE)	Emberá-Chamí (Choco)	Aguirre-Licht (1998)
Y22	Yes (NVNE)	Emerillon (Tupí)	Rose (2003)
Y23	Yes (NVNE)	Gavião do Jiparaná (Tupí)	Moore (1984)
Y24	Yes (NVNE)	Gavião do Pará (Macro-Ge)	Amado (2004)
Y25	Yes (MP)	Guahibo (Guahiban)	Kondo & Kondo (1972)
Y26	Yes (NVNE)	Guajá (Tupí)	Nascimento (2008)
Y27	Yes (NVNE)	Guarayu (Tupí)	Ureyu (2003)
Y28	Yes (MP)	Huambisa (Jivaroan)	Beasley & Pike (1957)
Y29	Yes (MP)	Iñapari (Arawak)	Parker (1999)
Y30	Yes (MP)	Jurúna (Tupí)	Fargetti (1992)
Y31	Yes (NVNE)	Kaiwá (Tupí)	Bridgeman (1961)
Y32	Yes (MP)	Kamayura (Tupí)	Seki (2000)

No.	V-Ũ?	Language (Family)	Source
Y33	Yes (MP)	Kanoé (Isolate)	Bacelar (2004)
Y34	Yes (MP)	Katukína (Panoan)	Barros (1987)
Y35	Yes (NVNE)	Kayabí (Tupí)	Souza (2004)
Y36	Yes (NVNE)	Kithualhu (Nambiquaran)	Telles & Wetzels (2011)
Y37	Yes (MP)	Kogi (Chibchan)	Gawthorne & Hensarling (1984)
Y38	Yes (MP)	Koreguaje (Tucanoan)	Cook & Criswell (1993)
Y39	Yes (NVNE)	Kuikúro-Kakapálo (Carib)	Meira & Franchetto (2005)
Y40	Yes (NVNE)	Kuruáya (Tupí)	Mendes Junior (2007)
Y41	Yes (MP)	Kwaza (Isolate)	van der Voort (2000)
Y42	Yes (NVNE)	Latunde (Nambiquaran)	Telles & Wetzels (2011)
Y43	Yes (MP)	Macuna (Tucanoan)	Smothermon et al. (1995)
Y44	Yes (NVNE)	Mosetén de Covendo (Mosetenan)	Sakel (2011)
Y45	Yes (NVNE)	Mosetén de Santa Ana (Mosetenan)	Sakel (2011)
Y46	Yes (NVNE)	Nheengatú (Tupí)	Moore et al. (1993)
Y47	Yes (NVNE)	Northern Emberá (Choco)	Hoyos Benítez (2000)
Y48	Yes (NVNE)	Nukini (Panoan)	Gomes (2009)
Y49	Yes (MP)	Ocaina (Witotoan)	Agnew & Pike (1957)
Y50	Yes (MP)	Páez (Isolate)	Rojas Curieux (1998)
Y51	Yes (NVNE)	Palikúr (Arawak)	Launey (2003)
Y52	Yes (MP)	Panará (Macro-Ge)	Dourado (2001)
Y53	Yes (MP)	Paraguayan Guaraní (Tupí)	Walker (1999)
Y54	Yes (NVNE)	Parkateje (Macro-Ge)	de Nazaré de Oliveira (2003)

No.	V-Ũ?	Language (Family)	Source
Y55	Yes (MP)	Pisamira (Tucanoan)	de Pérez (2000)
Y56	Yes (NVNE)	Rikbaktsa (Macro-Ge)	Silva (2005)
Y57	Yes (MP)	Sáliba (Salivan)	González Rátiva & Estrada Ramírez (2008)
Y58	Yes (MP)	Sanumá (Yanomam)	Borgman (1990)
Y59	Yes (MP)	Sateré-Mawé (Tupí)	da Silva (2005)
Y60	Yes (NVNE)	Shuar (Jivaroan)	Adelaar & Muysken (2004)
Y61	Yes (MP)	Siona (Tucanoan)	Wheeler (2000)
Y62	Yes (NVNE)	Siriano (Tucanoan)	Criswell & Brandrup (2000)
Y63	Yes (NVNE)	Suruí (Tupí)	van der Meer (1982)
Y64	Yes (NVNE)	Tanimuca-Retuarã (Tucanoan)	Ardila (2000)
Y65	Yes (MP)	Tapieté (Tupí)	González (2005)
Y66	Yes (NVNE)	Tapirapé (Tupí)	Praça (2007)
Y67	Yes (NVNE)	Tariana (Arawak)	Aikhenvald (2003)
Y68	Yes (MP)	Tatuyo (Tucanoan)	Whisler & Whisler (1976)
Y69	Yes (NVNE)	Tsáfiki (Barbacoan)	Moore (1962)
Y70	Yes (NVNE)	Tsimané (Mosetenan)	Sakel (2011)
Y71	Yes (MP)	Tucano (Tucanoan)	Welch & West (2000)
Y72	Yes (MP)	Tuyuca (Tucanoan)	Barnes & Silzer (1976)
Y73	Yes (NVNE)	Urarina (Isolate)	Olawsky (2006)
Y74	Yes (MP)	Waorani (Isolate)	Saint & Pike (1962)
Y75	Yes (–)	Waurá (Arawak)	Richards (1977)
Y76	Yes (MP)	Wayoró (Tupí)	de Souza Nogueira (2011)

No.	V-Ũ?	Language (Family)	Source
Y77	Yes (NVNE)	Xerénte (Macro-Ge)	de Souza (2008b)
Y78	Yes (NVNE)	Xokleng (Macro-Ge)	Gakran (2005)
Y79	Yes (NVNE)	Yaminawa (Panoan)	Faust & Loos (2002)
Y80	Yes (MP)	Yanomámi (Yanomam)	Migliazza (1972)
Y81	Yes (NVNE)	Yora (Panoan)	Anonymous (2001)
Y82	Yes (NVNE)	Yurutí (Tucanoan)	Kinch & Kinch (2000)
Y83	Yes (NVNE)	Zo'é (Tupí)	Cabral (2009)
N1	No	Abipon (Guaicuru)	Najilis (1966)
N2	No	Achagua (Arawak)	Wilson & Levinsohn (1992)
N3	No	Akurio (Carib)	Meira (1998)
N4	No	Alacufe, Central (Alacufan)	Barros (2005)
N5	No	Alacufe, Southern (Alacufan)	Barros (2005)
N6	No	Araona (Tacanan)	Pitman (1981)
N7	No	Arara do Acre (Panoan)	de Souza (2012)
N8	No	Arára, Pará (Carib)	Ferreira Alvez (2010)
N9	No	Asháninka (Arawak)	Dirks (1953)
N10	No	Ashéninka, Apurucayali (Arawak)	Payne et al. (1982)
N11	No	Ashéninka, Perené (Arawak)	Mihas (2010)
N12	No	Ashéninka, Pichis (Arawak)	Payne (1982)
N13	No	Asuriní do Tocantins (Tupí)	Nicholson (2009)
N14	No	Ayacucho Quechua (Quechua)	Ruiz (1976)
N15	No	Aymara, Central (Aymaran)	Apaza (2007)



No.	V-Ũ?	Language (Family)	Source
N16	No	Aymara, Chilean (Aymaran)	Poblete M. & Salas (1997)
N17	No	Baniwa, Central (Arawak)	Ramirez (2001)
N18	No	Baniwa, Rio Negro (Arawak)	Mosonyi (2000)
N19	No	Baure (Arawak)	Danielsen (2007)
N20	No	Bolivian Quechua (Quechua)	Bills et al. (1969)
N21	No	Bora (Boran)	Weber & Thiesen (2001)
N22	No	Border Kuna (Chibchan)	Adelaar & Muysken (2004)
N23	No	Borôro (Macro-Ge)	Nonato (2008)
N24	No	Cabiyari (Arawak)	Ramirez (2001)
N25	No	Cajamarca Quechua (Quechua)	Castillo (2006)
N26	No	Callawaya (Mixed)	Adelaar & Muysken (2004)
N27	No	Camsá (Isolate)	Howard (1972)
N28	No	Candoshi-Shapra (Isolate)	Tuggy (1981)
N29	No	Capanahua (Panoan)	Elías-Ulloa (2009)
N30	No	Caquinte (Arawak)	Swift (1988)
N31	No	Carib, French Guinea (Carib)	Renault-Lescure (2009)
N32	No	Carib, Suriname (Carib)	Courtz (2008)
N33	No	Carib, Venezuela (Carib)	Álvarez (2003)
N34	No	Carijona (Carib)	Meira (1998)
N35	No	Cashibo-Cacataibo (Panoan)	Zariquiey (2011)
N36	No	Cavineña (Tacanan)	Guillaume (2008)
N37	No	Chachapoyas Quechua (Quechua)	Chaparro (1985)

No.	V-Ũ?	Language (Family)	Source
N38	No	Chacobo (Panoan)	Prost (1967)
N39	No	Chamicuro (Arawak)	Parker (2001)
N40	No	Chaná (Charruan)	Jaime & Barros (2013)
N41	No	Chipaya (Uru-Chipaya)	Olson (1967)
N42	No	Cholon (Hibito-Cholon)	Alexander-Bakkerus (2005)
N43	No	Chorote (Mataco)	Gerzenstein (1978)
N44	No	Chulupí (Mataco)	Campbell & Grondona (2007)
N45	No	Cuiba (Guahiban)	Galindo (2000)
N46	No	Curripaco (Arawak)	Granadillo (2008)
N47	No	Cuzco-Collao Quechua (Quechua)	Parker (2007)
N48	No	Damana (Chibchan)	Amaya (2000)
N49	No	Dení (Arawan)	Carvalho (2013)
N50	No	Ese Eja, Peru (Tacanan)	Chavarria (2012)
N51	No	Ese Ejja (Tacanan)	Vuillermet (2012)
N52	No	Ferreñafe Quechua (Quechua)	Taylor (1982)
N53	No	Guajajára (Tupí)	Bendor-Samuel (1972)
N54	No	Guambiano (Barbacoan)	Branks & Branks (1973)
N55	No	Günün Yajich (Isolate)	Barros (2005)
N56	No	Guató (Macro-Ge)	Postigo (2009)
N57	No	Guayabero (Guahiban)	Keels (1985)
N58	No	Hixkaryána (Carib)	Derbyshire (1985)
N59	No	Huallaga Huánuco Quechua (Quechua)	Weber (1989)

No.	V-Ũ?	Language (Family)	Source
N60	No	Huitoto, Minica (Witotoan)	Minor & Minor (1976)
N61	No	Huitoto, Murui (Witotoan)	Petersen & Patiño (2000)
N62	No	Ignaciano (Arawak)	Ott & Ott (1967)
N63	No	Ika (Chibchan)	Landaburu (2000b)
N64	No	Ikpeng (Carib)	Pachêco (2001)
N65	No	Inga, Highland (Quechua)	Levinsohn & Jansasoy (2000)
N66	No	Inga, Jungle (Quechua)	Maffla Bilbao (1976)
N67	No	Iquito (Zaparoan)	Michael (2012)
N68	No	Itonama (Isolate)	Crevels (2002)
N69	No	Jamamadí (Arawan)	Dixon (2004)
N70	No	Japreria (Carib)	Oquendo (2004)
N71	No	Jaqaru (Aymaran)	Hardman (1966)
N72	No	Jarawara (Arawan)	Vogel (1993)
N73	No	Jauja-Huanca Quechua (Quechua)	Wroughton (1996)
N74	No	Kaingang (Macro-Ge)	Neto (2007)
N75	No	Karirí-Xocó, Dzubukuá (Isolate)	de Queiroz (2012)
N76	No	Katukina (Katukinan)	dos Anjos (2011)
N77	No	Kawesqar (Alacufan)	Aguilera F. (2001)
N78	No	Kaxararí (Panoan)	Sousa (2004)
N79	No	Kinikinao (Arawak)	de Souza (2008a)
N80	No	Kokama-Kokamilla (Tupí)	Vallejos (2010)
N81	No	Korubo (Panoan)	de Oliveira (2009)

No.	V-Ŷ?	Language (Family)	Source
N82	No	Kulina (Arawan)	Adams & de Powlison (1976)
N83	No	Kunza (Isolate)	Adelaar & Muysken (2004)
N84	No	Lokono (Arawak)	Pet (1988)
N85	No	Lule (Isolate)	Barros (2001)
N86	No	Macaguán (Guahiban)	Lobo-Guerrero & Herrera (2000)
N87	No	Macushi (Carib)	Carson (1981)
N88	No	Maka (Mataco)	Gerzenstein (1994)
N89	No	Manchinere (Arawak)	dos Santos Silva (2008)
N90	No	Mapoyo (Carib)	Mattei-Muller (2003)
N91	No	Mapudungun (Araucanian)	Barros (2005)
N92	No	Matís (Panoan)	Ferreira (2005)
N93	No	Matsés (Panoan)	Fleck (2003)
N94	No	Mehináku (Arawak)	Corbera Mori (2008)
N95	No	Miraña (Boran)	Seifart (2005)
N96	No	Mochica (Isolate)	Torero (1997)
N97	No	Mocoví (Guaicuru)	Grondona (1998)
N98	No	Movima (Isolate)	Haude (2006)
N99	No	Muinane (Boran)	Walton & Walton (1972)
N100	No	Muisca (Chibchan)	Adelaar & Muysken (2004)
N101	No	Muniche (Isolate)	Michael et al. (2013)
N102	No	Muylaq' Aymara (Aymaran)	Coler (2014)
N103	No	Nanti (Arawak)	Michael (2008)

No.	V-Ŷ?	Language (Family)	Source
N104	No	Nomatsigenga (Arawak)	Shaver (1996)
N105	No	N. Junín Quechua, San Pedro de Cajas (Quechua)	Adelaar 1977
N106	No	N. Junín Quechua, Tarma (Quechua)	Adelaar 1977
N107	No	Omagua (Tupí)	O'Hagan & Sandy (2010)
N108	No	Panare (Carib)	Hall & Villalon (1988)
N109	No	Panobo (Panoan)	Gomes (2010)
N110	No	Parakanã (Tupí)	da Silva (2003)
N111	No	Paraujano (Arawak)	Patte (1989)
N112	No	Paresí (Arawak)	da Silva (2013)
N113	No	Paumarí (Arawan)	Dixon (2004)
N114	No	Pemon, Arekuna (Carib)	Edwards (1978)
N115	No	Pemon, Tarepang (Carib)	Pessoa (2006)
N116	No	Pémono (Carib)	Mattei-Muller (2003)
N117	No	Piapoco (Arawak)	Mosonyi (2000)
N118	No	Piaroa (Salivan)	Mosonyi (2000)
N119	No	Pilagá (Guaicuru)	Vidal (2001)
N120	No	Pirahã (Mura)	Everett (1979)
N121	No	Pumé (Isolate)	Mosonyi et al. (2000)
N122	No	Purí (Macro-Ge)	Neto (2007)
N123	No	Resígaro (Arawak)	Allin (1976)
N124	No	Reyesano (Tacanan)	Guillaume (2012)
N125	No	Sabanê (Nambiquaran)	Antunes de Araujo (2004)

No.	V-Ũ?	Language (Family)	Source
N126	No	Salasca Quechua (Quechua)	Chango Masaquiza & Marlett (2008)
N127	No	San Martin Quechua (Quechua)	Coombs et al. (1976)
N128	No	Santiago del Estero Quechua (Quechua)	Alderetes (2001)
N129	No	Saynawa (Panoan)	Couto (2010)
N130	No	Selk'nam (Chon)	Rojas-Berscia (2014)
N131	No	Shanenawa (Panoan)	Cândido (2004)
N132	No	Shawi (Cahuapanan)	Barraza (2005)
N133	No	Shipibo (Panoan)	Elías-Ulloa (2010)
N134	No	Shiwilu (Cahuapanan)	Valenzuela & Gussenhoven (2013)
N135	No	Suruahá (Arawan)	Suzuki (1997)
N136	No	Tacana (Tacanan)	Ottaviano & Ottaviano (1965)
N137	No	Taushiro (Isolate)	Alicea (1975)
N138	No	Tehuelche (Chon)	Barros (2005)
N139	No	Tembé (Tupí)	Duarte (2003)
N140	No	Tena Quechua (Quechua)	Orr & Wisley (1981)
N141	No	Terêna (Arawak)	Martins (2009)
N142	No	Tinigua (Isolate)	Tobar (2000)
N143	No	Toba, Lañagashik (Guaicuru)	Klein (1978)
N144	No	Trió (Carib)	Meira (1999)
N145	No	Trumai (Isolate)	Guiardello (1999)
N146	No	Tunebo, Central (Chibchan)	Headland (1997)
N147	No	Umotína (Macro-Ge)	Lima (1995)

No.	V-Ũ?	Language (Family)	Source
N148	No	Uru (Uru-Chipaya)	Muysken (2000)
N149	No	Vilela (Isolate)	Barros (2001)
N150	No	Waimiri-Atroarí (Carib)	Bruno (2003)
N151	No	Waiwai (Carib)	Hawkins (1998)
N152	No	Wapichana (Arawak)	dos Santos (2006)
N153	No	Warao (Isolate)	Romero-Figueroa (1997)
N154	No	Warekena (Arawak)	Aikhenvald (1998)
N155	No	Wayana (Carib)	Tavares (2006)
N156	No	Wayúu (Arawak)	Mansen (1972)
N157	No	Wichí, Mision la Paz (Mataco)	Avram (2008)
N158	No	Woun Meu (Choco)	Fonnegra (2000)
N159	No	Xiriâna (Arawak)	Ramirez (1992)
N160	No	Yaathe (Macro-Ge)	da Silva (2011)
N161	No	Yabarana (Carib)	Mattei-Muller (2003)
N162	No	Yahgan (Isolate)	Barros (2005)
N163	No	Yameo (Peba-Yaguan)	Liclan & Marlett (1990)
N164	No	Yánesha (Arawak)	Fast (1953)
N165	No	Yanomamö (Arawak)	Mosonyi et al. (2000)
N166	No	Yavitero (Arawak)	Mujica (1992)
N167	No	Yawalapití (Arawak)	Mujica (1992)
N168	No	Yawanawa (Panoan)	Cruvinel (2009)
N169	No	Yekwana (Carib)	Cáceres (2007)

No.	V-Ũ?	Language (Family)	Source
N170	No	Yine (Arawak)	Sebastián & Marlett (2008)
N171	No	Yucuna (Arawak)	Schauer & Schauer (2000)
N172	No	Yukpa, de Irapa (Carib)	Meira (2003)
N173	No	Yukpa, Macoíta (Carib)	Hildebrant (1958)
N174	No	Yuqui (Tupí)	Villefañe (2004)
N175	No	Yurakaré (Isolate)	van Gijn (2006)

### 3.7 Appendix B: summary of vowel neutralization survey

This appendix provides information for each of the languages included in the vowel neutralization survey. If a cell is shaded, it means that contrasts in vocalic nasality are neutralized in that context; if it is unshaded, that means that contrasts in vocalic nasality are not known to be neutralized in that context. If a cell contains ‘??’, this means that while the author claims that contrasts in vocalic nasality are neutralized before all nasal consonants, the only examples of neutralization provided are in the VN]<sub>σ</sub> context. If a cell contains ‘–’, this means that independent phonotactic restrictions (i.e. no coda nasals) make the given context impossible to examine.

In all cases, the language names provided here are those given by Ethnologue. Where they differ significantly, language names provided by the cited sources are after a slash.

Table 3.4: List of languages included in vowel neutralization survey

No.	Restrictions?	Language (Family) Source	Neut. Contexts		
			NV	VN] <sub>σ</sub>	V] <sub>σ</sub> N
Y1	Yes	Aceh (Austronesian) Durie 1985			
Y2	Yes	Drubea/Ndumbea (Austronesian) Gordon & Maddieson 1999			
Y3	Yes	Éwé (Niger-Congo) Westermann 1930			
Y4	Yes	Gbaya-Bossangoa (Gbeya) Samarin 1966			
Y5	Yes	Hindi (Indo-European) Ohala 1975			??
Y6	Yes	Ho-Chunk/Winnebago (Siouan) Miner 1989			



No.	Restrictions?	Language (Family) Source	Neut. Contexts		
			NV	VN] <sub><math>\sigma</math></sub>	V] <sub><math>\sigma</math></sub> N
Y7	Yes	Khana (Niger-Congo) Ikoro 1996			
Y8	Yes	Kiowa (Kiowa-Tanoan) Watkins 1984			
Y9	Yes	Lakota (Siouan) Rood & Taylor 1996			
Y10	Yes	Mazatec, Jalapa de Díaz (Otomanguean) Silverman et al. 1995			
Y11	Yes	Mbay (Nilo-Saharan) Keegan 1997			??
Y12	Yes	Mixtec, Ataláhuca (Otomanguan) Alexander 1980		–	
Y13	Yes	Mixtec, Coatzospan (Otomanguean) Gerfen 1999		–	
Y14	Yes	Mbembe (Niger-Congo) Kemmermann 2014		–	–
Y15	Yes	Me'phaa, Malinaltepec/Tlanpaneca (Otomanguean) Suárez 1983		–	–
Y16	Yes	Navaho (Athabaskan) Sapir & Hoijer 1967			
Y17	Yes	Niellim/Lua (Niger-Congo) Boyeldieu 1985			
Y18	Yes	Nupe-Nupe-Tako (Niger-Congo) Dunstan 1969		–	
Y19	Yes	Oka-Akoko (Niger-Congo) Oyebade 1985		–	
Y20	Yes	Paicî (Austronesian) Gordon & Maddieson 2004			
Y21	Yes	Sanumá (Yanomaman) Borgman 1990		–	
Y22	Yes	Saramaccan (Creole, English based) McWhorter & Good 2012			
Y23	Yes	St. Lucian Creole (Creole, French based) Carrington 1984			
Y24	Yes	Supyire (Niger-Congo) Carlson 1994			
Y25	Yes	Tewa, Rio Grande (Kiowa-Tanoan) Speirs 1966			
Y26	Yes	Tîrî (Austronesian) Osumi 1995			
Y27	Yes	Urarina (Isolate) Olawsky 2006		–	
Y28	Yes	Vai (Niger-Conto) Welmers 1976			

No.	Restrictions?	Language (Family) Source	Neut. Contexts		
			NV	VN] <sub><math>\sigma</math></sub>	V] <sub><math>\sigma</math></sub> N
Y29	Yes	Xârâcùù (Austronesian) Lynch 2002b			
Y30	Yes	Yakoma (Niger-Congo) Boyeldieu 1975			
Y31	Yes	Yoruba (Niger-Congo) Bamgbose 1966		–	
Y32	Yes	Yuchi (Isolate) Crawford 1973		–	
N1	None discussed	Akan (Niger-Congo) Dolphyne (1988)			
N2	None discussed	Angolar (Creole, Portuguese Based) Lorenzino 1988			
N3	None discussed	Anguthimri (Pama-Nyungan) Crowley 1981			
N4	None discussed	Apache, Chiricahwa (Athabaskan) Hoijer 1945			
N5	None discussed	Apalaí (Cariban) Koehn & Koehn 1986			
N6	None discussed	Assiniboine (Siouan) Levin 1964			
N7	None discussed	Avatime (Niger-Congo) Kropp Dakubu & Ford 1988			
N8	None discussed	Awutu, Efutu (Niger-Congo) Obeng 2008			
N9	None discussed	Baré (Arawakan) Aikhenvald 1995			
N10	None discussed	Belize Kriol English (Creole, English Based) Greene 1999			
N11	None discussed	Biloxi (Siouan) Einaudi 1976			
N12	None discussed	Brazilian Portuguese (Indo-European) de Medeiros 2011			
N13	None discussed	Breton (Indo-European) Press 1987			
N14	None discussed	Canela-Krahô (Macro-Ge) Popjes & Popjes 1986			
N15	None discussed	Cemuhî (Austronesian) Lynch 2002a			
N16	None discussed	Chickasaw (Muskogean) Munro 2005			
N17	None discussed	Choctaw (Muskogean) Broadwell 2005			
N18	None discussed	Dagaare (Niger-Congo) Bodomo 1997			

No.	Restrictions?	Language (Family) Source	Neut. Contexts		
			NV	VN] <sub><math>\sigma</math></sub>	V] <sub><math>\sigma</math></sub> N
N19	None discussed	Dangme (Niger-Congo) Kropp Dakubu 1987			
N20	None discussed	Dene/Chipewyan (Athabaskan) Li 1946			
N21	None discussed	Dogon, Jamsay (Niger-Congo) Heath 2008			
N22	None discussed	Dogon, Tommo So (Niger-Congo) McPherson 2013			
N23	None discussed	Emberá (Chocoan) Herrera 2002			
N24	None discussed	Fon (Niger-Congo) Lefebvre & Brousseau 2002			
N25	None discussed	French (Indo-European) Cohn 1990			
N26	None discussed	Gbaya Kara (Niger-Congo) Monino & Roulon 1972			
N27	None discussed	Hupdë (Nadahup) Epps 2008			
N28	None discussed	Ijo (Niger-Congo) Dunstan 1969; Harry 2004			
N29	None discussed	Jèrriais/Norman French (Indo-European) Liddicoat 1994			
N30	None discussed	Kaapor (Tupian) Kakumasu 1986			
N31	None discussed	Kabba (Nilo-Saharan) Moser 2004			
N32	None discussed	Karok (Isolate) Bright 1957			
N33	None discussed	Koromfé (Niger-Congo) Rennison 1997			
N34	None discussed	Kwaza (Isolate) van der Voort 2004			
N35	None discussed	Makaa (Niger-Congo) Heath 2003			
N36	None discussed	Mbum (Niger-Congo) Hagège 1970			
N37	None discussed	Mohawk, Akwesasne (Iroquoian) Bonvillain 1973			
N38	None discussed	Newar, Dolakha (Sino-Tibetan) Genetti 2007			
N39	None discussed	Ngäbere/Guaymí (Chibchan) Pacheco 2008			
N40	None discussed	Ngambay (Nilo-Saharan) Vandame 1963			

No.	Restrictions?	Language (Family) Source	Neut. Contexts		
			NV	VN] <sub><math>\sigma</math></sub>	V] <sub><math>\sigma</math></sub> N
N41	None discussed	Ngbaka (Niger-Congo) Thomas 1963			
N42	None discussed	Nishnaabemwin (Algonquian) Valentine 2001			
N43	None discussed	Objibwa, Eastern (Algonquian) Bloomfield 1956			
N44	None discussed	Onondaga (Iroquoian) Barrie 2015			
N45	None discussed	Osage (Siouan) Quintero 2004			
N46	None discussed	Otomi, Mezquital (Otomanguean) Hess 1968			
N47	None discussed	Páez (Paezan) Jung 2008			
N48	None discussed	Popolocal, Mezontla (Otomanguean) Veerman-Leichsenring 1991			
N49	None discussed	Quapaw (Siouan) Rankin 2005			
N50	None discussed	Seneca (Iroquoian) Chafe 2015			
N51	None discussed	Siwu (Niger-Congo) Kropp Dakubu & Ford 1988			
N52	None discussed	Slave (Athabaskan) Rice 1989			
N53	None discussed	Songhay, Koyra Chiini (Nilo-Saharan) Heath 1999a			
N54	None discussed	Songhay, Koyraboro Senni (Nilo-Saharan) Heath 1999b			
N55	None discussed	Suga/Nizaa (Niger-Congo) Endresen 1991			
N56	None discussed	Susu (Niger-Congo) Houis 1963			
N57	None discussed	Tariana (Arawakan) Aikhenvald 2003			
N58	None discussed	Tewa, Santa Clara (Kiowa-Tanoan) Hoijsen & Dozier 1949			
N59	None discussed	Tiwa, Northern, Taos (Kiowa-Tanoan) Trager 1946			
N60	None discussed	Tsimané/Mosetén (Mosetenan) Sakel 2004			
N61	None discussed	Tuscarora (Iroquoian) Mithun Williams 1976			
N62	None discussed	Vute (Niger-Congo) Guarisma 1978			

No.	Restrictions?	Language (Family) Source	Neut. Contexts		
			NV	VN] <sub><math>\sigma</math></sub>	V] <sub><math>\sigma</math></sub> N
N63	None discussed	Wampanoag/Massachusetts (Algonquian) Goddard & Bragdon 1988			
N64	None discussed	Wandala (Afro-Asiatic) Frajzyngier 2012			
N65	None discussed	Waorani/Auca (Isolate) Saint & Pike 1962			
N66	None discussed	Yuki (Yukian) Sawyer & Schlichter 1984			

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## Chapter 4

# Effects of Vowel Nasalization on the Distribution of Nasal-Stop Sequences

Chapters 2 and 3 of this study have argued that, in order to explain the distributional properties of phonemic and allophonic NCs, it is necessary for constraints on contrast to be part of the synchronic phonological grammar. If the constraints on contrast proposed in this thesis are part of the phonological grammar, we might expect to find evidence that they can interact. This chapter documents two such cases, both of which concern interactions between the distribution of NCs and the distribution of vocalic nasality.

While one of the main results of Chapter 2 is that many languages only license an N–NC contrast where there is a following vowel available, it did not focus on the vowel’s identity. As shown by Beddor & Onsuwan (2003), however, the following vowel’s identity is crucial: reliable identification of NCs is dependent on the presence of a following segment bearing oral formants, and reliable identification of Ns is dependent on the presence of a following segment bearing nasal formants.

If constraints on the distribution of NCs are constraints on contrast, one predicted consequence is that there should be an observable cross-linguistic dispreference for NC $\tilde{V}$  sequences: in NC $\tilde{V}$ , the cues needed to distinguish NC from N are reduced. In this chapter, I evaluate this prediction by investigating two contexts in which NC $\tilde{V}$  (likely) arises. The first is in sequences of NCs (or NC<sub>1</sub>VNC<sub>2</sub> sequences), where likely nasalization of the intervening vowel would enhance cues to the C–NC<sub>2</sub> contrast, but reduce cues to the N–NC<sub>1</sub> contrast. The second is when an NC is followed by a phonemically nasal vowel (NC $\tilde{V}$ ). In the NC $\tilde{V}$  context, realization of oral transitions following NC would enhance the cues to N–NC, but reduce the amount of nasality in the following nasal vowel. This, in turn, might compromise important cues to the contrast in vocalic nasality. Accurate identification of nasal vowels has been shown to be at least partially dependent on the perceptual summation of acoustic nasalization over time (Whalen & Beddor 1989); presumably, the less a nasal vowel is acoustically nasalized, the less distinct it is from an oral vowel. In support of these predictions, I show that there is an observable typological dispreference for both NC<sub>1</sub>VNC<sub>2</sub> (sections 4.1–4.6) and NC $\tilde{V}$  (sections 4.6–4.7) and that asymmetries in the typologies of both phenomena are naturally predicted by the contrast-based account.

The two phenomena discussed in this chapter show that constraints on contrast can conflict, and that such conflicts have observable consequences – both typologically, and within the phonologies of individual languages. In this way, the phenomena discussed in this chapter also provide further support for the major claim of this study: constraints on the distribution of nasal-stop sequences are constraints on contrast.

## 4.1 Introduction to nasal cluster effects

In many languages, consecutive NC sequences are dispreferred (descriptively, \*NC<sub>1</sub>VNC<sub>2</sub>). In languages where this restriction is active, there are a number of attested repairs. For example, in many cases, NC<sub>1</sub> is realized as a plain nasal consonant (1); this process is well-known in the Bantu literature as Meinhof’s Law (after Meinhof 1932, who discovered it). Other repairs include the realization of NC<sub>2</sub> as a plain oral consonant (2); this process is also known as the Kwanyama Law.

(1) NC<sub>1</sub> nasalization in Ngaju Dayak (Blust 2012:372)

- a. /ma**N**+bando/ → [ma-mando] ‘turn against’  
(cf. [mam-bagi] ‘divide’)
- b. /ma**N**+gundu/ → [ma-ŋundul] ‘wrap up’  
(cf. [maŋ-gila] ‘drive crazy’)

(2) NC<sub>2</sub> oralization in Gurindji (McConvell 1988:138)<sup>1</sup>

- a. /ka**ŋ**ju+mpal/ → [ka**ŋ**ju+pal] ‘across below’  
(cf. [kajira-mpal] ‘across the north’)
- b. /ka**n**ka+mpa/ → [ka**n**ka-pa] ‘upstream’  
(cf. [kani-mpa] ‘downstream’)

To date, most of the work on nasal cluster effects has addressed the following question: what is the nature of the markedness constraint that drives these alternations? There are two currently existing answers to this question. Many analysts (e.g. Alderete 1997, Blust 2012) claim that the alternations in (1–2) are examples of dissimilation driven by an OCP constraint (i.e. \*NC...NC), which penalizes words containing more than one NC sequence. Others (Herbert 1977, 1986; Jones 2000) argue that these alternations are driven by articulatory or perceptual considerations.

I argue, following insights by Herbert and Jones, that (1–2) and other similar alternations occur in response to constraints that penalize insufficiently distinct contrasts. In NC<sub>1</sub>VNC<sub>2</sub>, anticipatory nasalization from NC<sub>2</sub> – which is necessary for NC<sub>2</sub> to remain sufficiently distinct from a plain oral consonant – renders NC<sub>1</sub> insufficiently distinct from a plain nasal consonant. The repairs, then, are motivated by a desire to avoid insufficiently distinct contrasts. In what follows, I show that the contrast-based approach correctly predicts conditions on possible repairs to NC<sub>1</sub>VNC<sub>2</sub>, implicational generalizations as to which NC<sub>1</sub>VNC<sub>2</sub> sequences are repaired, and a universal generalization regarding the locality of repairs. We will see that, by contrast, the alternative OCP-motivated analysis cannot predict these generalizations – nor can it account for them in a principled way.

## 4.2 The typology of possible repairs

If a language bans NC<sub>1</sub>VNC<sub>2</sub>, there are many logically possible repairs; here I will focus on four. A language might delete the nasal from either NC<sub>1</sub> or NC<sub>2</sub> (a repair I call *oralization*), neutralizing one of the C–NC contrasts. A language could also delete the stop from either NC<sub>1</sub> or NC<sub>2</sub> (a repair I call *nasalization*), neutralizing one of the N–NC contrasts. A survey of 67 languages, drawing from reference grammars as well as previous literature (e.g. Meeussen 1963, Herbert 1977,

<sup>1</sup>The Gurindji transcriptions in this chapter for the most part mirror McConvell’s. Several graphemes have however been converted into IPA symbols. These are: <rt> = /t/, <j> = /j/, <rn> = /ŋ/, <ny> = /ɲ/, <ng> = /ŋ/, <rl> = /l/, <ly> = /ʎ/, <tr> = /r/, <r> = /ɹ/, <y> = /j/.



McConvell 1988), shows that all four of these repairs are attested.<sup>2</sup> The results are summarized in (3); see Appendix A (section 4.9) for the full survey. (One language, Mori Bawah (Esser & Mead 2011, Blust 2012) has been counted twice: whether it exhibits NC<sub>1</sub> or NC<sub>2</sub> oralization depends on morphological context, as discussed in section 4.2.2.) It should be noted that in this survey I made no attempt to differentiate NC sequences that function as “segments” from those that function as “clusters”, as there is no *a priori* reason to believe that a difference in their representational status should contribute in any way to a difference in their ability to co-occur with other NCs (for related discussion on this point, see Chapter 2.4). In addition, through the course of conducting the survey, I found no evidence to suggest that making such a distinction was necessary.

In addition to the repairs listed in (3), there is also one language that lacks alternations but displays a static restriction on NC<sub>1</sub>VNC<sub>2</sub>: in Saramaccan (McWhorter & Good 2012), words containing multiple nasal-stop sequences are exceedingly rare (see section 4.6.2 for some discussion).

(3) Repairs to banned NC<sub>1</sub>VNC<sub>2</sub>

	Repair	Change (underlined)	No.	Example
a.	NC <sub>1</sub> oralization	/NC <sub>1</sub> V NC <sub>2</sub> / → [ <u>C</u> <sub>1</sub> V NC <sub>2</sub> ]	2	Timugon Murut (Blust 2012)
b.	NC <sub>2</sub> oralization	/NC <sub>1</sub> V NC <sub>2</sub> / → [NC <sub>1</sub> V <u>C</u> <sub>2</sub> ]	14	Kwanyama (Herbert 1977)
c.	NC <sub>1</sub> nasalization	/NC <sub>1</sub> V NC <sub>2</sub> / → [ <u>N</u> <sub>1</sub> V NC <sub>2</sub> ]	51	Ngaju Dayak (Blust 2012)
d.	NC <sub>2</sub> nasalization	/NC <sub>1</sub> V NC <sub>2</sub> / → [NC <sub>1</sub> V <u>N</u> <sub>2</sub> ]	1	Gurindji, Western (McConvell 1988)

The typology of repairs is consistent with the predictions of a contrast-based and an OCP-motivated account. Under an OCP-motivated analysis, all repairs eliminate one of the NCs, leading to satisfaction of \*NC...NC. Under a contrast-based analysis, all repairs alleviate in some way the perceptual problem posed by NC<sub>1</sub>VNC<sub>2</sub>. In the following subsections, I develop a contrast-based analysis that is capable of accounting for the repairs in (3a–c) – in other words, all of the attested repairs except NC<sub>2</sub> nasalization. Later on (in section 4.3.1), once more pieces of the analysis are in place, I show that the analysis correctly predicts that the fourth repair, NC<sub>2</sub> nasalization, should only occur in a restricted set of circumstances. Some problems for the alternative OCP-motivated analysis are discussed briefly in section 4.3.5.

Note that the analysis presented below does not take into consideration the frequency asymmetries among the repairs that are evident in (3) – namely that NC<sub>1</sub> nasalization is more common than all other repairs. I make no attempt to incorporate these asymmetries because I believe that they are largely, or perhaps entirely, due to the composition of the survey. A majority of the survey is composed of languages discussed by Meeussen (1963), whose substantial survey includes only languages exhibiting NC<sub>1</sub> nasalization. An additional asymmetry between the frequencies of NC<sub>2</sub> and NC<sub>1</sub> oralization is likely due to morphological properties of the surveyed languages, as most languages with oralization repairs are suffixing languages. (The relationship between morphology and choice of repair is discussed in section 4.2.2.)

<sup>2</sup>Other possible repairs, such as metathesis of NC<sub>2</sub> /NC<sub>1</sub> V NC<sub>2</sub>/ → [NC<sub>1</sub> V CN<sub>2</sub>], appear to be unattested. I assume that these other repairs are ruled out due to considerations of P-Map faithfulness (Steriade 2009), i.e. the perceptual consequences of the unattested repairs would be more salient than the consequences of the attested repairs. This point, however, deserves further research. (In the particular case of metathesis, it is also worth noting that CN sequences are cross-linguistically infrequent; perhaps a dispreference for CNs contributes to the absence of this repair.)

### 4.2.1 Setting up the analysis

The source of the observed cross-linguistic dispreference for  $NC_1VNC_2$  can be linked to the fact that, in most languages, vowels preceding nasals are nasalized.<sup>3</sup> In most languages, then, the vowel that intervenes in an  $NC_1VNC_2$  sequence will be nasalized. This is diagrammed in (4); the relative amounts of vocalic nasality and orality are arbitrarily chosen, as they are not important at this point.

- (4) Vowel nasalization in  $NC_1VNC_2$
- |        |   |             |        |
|--------|---|-------------|--------|
| $NC_1$ | V | $\tilde{V}$ | $NC_2$ |
|--------|---|-------------|--------|

The anticipatory vowel nasalization in (4) likely reduces cues to the contrast between  $NC_1$  and N. As discussed in Chapter 2, experimental work has shown that the perception of the contrast between Ns and NCs is, at the very least, aided by the presence of a following vowel. For the contrast between Ns and voiced NCs (NDs), Beddor & Onsuwan (2003) have shown that, for speakers of Ikalanga (Bantu), presence of the appropriate external cues is essential: for accurate identification, N must be followed by a nasal vowel and ND must be followed by an oral vowel. Work by Kaplan (2008) on the perception of English N–NC contrasts suggests that the presence of a following vowel is also a cue to the contrast between Ns and voiceless NCs (NTs). In sum, a cue to the contrast between N and NC is a difference in the nasal vs. oral formant structure of the following segment, or  $\Delta$  *formant quality (following segment)* (or  $\Delta$  *formant quality* ( $S_2$ ); see Chapter 2 for further discussion).

Thus the dispreferred sequence,  $NC_1VNC_2$ , is one in which the N– $NC_1$  contrast is compromised. The claim is that nasal cluster effects occur in order to avoid insufficiently distinct N–NC contrasts. To formalize an analysis along these lines, I make a simplifying hypothesis, to be revisited later: for the N–NC contrast to be maximally distinct, N must be followed by a fully nasal vowel ( $\tilde{V}$ ) and NC must be followed by a fully oral vowel. We can state this requirement as a MINDIST constraint (Flemming 2002),  $\Delta$  FQUALITY ( $S_2$ -ALL) which requires N to be followed by a segment bearing nasal formants through its entire duration, and NC to be followed by a segment bearing oral formants through its entire duration ((5); for other uses of  $\Delta$  FQUALITY ( $S_2$ ), see Chapter 2).

- (5) MINDIST N–NC (FQUALITY ( $S_2$ -ALL)): assign one violation for every N–NC pair in the output that does not differ in the nasal vs. oral quality of the following segment, such that:
- a. N is followed by a segment that, from its beginning to its end, is marked by nasal formants; and
  - b. NC is followed by a segment that, from its beginning to its end, is marked by oral formants.

An example of a contrast that satisfies FQUALITY ( $S_2$ -ALL) is [NCV] vs. [NC $\tilde{V}$ ] (6). As NC is followed by a fully oral vowel and N by a fully nasal vowel, the contrast is sufficiently distinct.

- (6) FQUALITY ( $S_2$ -ALL) satisfied in [NCV] vs. [N $\tilde{V}$ ]

- |    |    |             |
|----|----|-------------|
| a. | NC | V           |
| b. | N  | $\tilde{V}$ |

An example of a contrast that violates FQUALITY ( $S_2$ -ALL) is [NC<sub>1</sub>V $\tilde{V}$ NC<sub>2</sub>] vs. [N<sub>1</sub> $\tilde{V}$ NC<sub>2</sub>] (7). While N<sub>1</sub> is followed by a fully nasal vowel, NC<sub>1</sub> is not followed by a fully oral vowel; anticipatory

<sup>3</sup>Recall from Chapter 3 that the extent of coarticulatory nasalization varies by language (see e.g. Jeong 2012) and by context: this latter point will be addressed in section 4.3.

nasalization from NC<sub>2</sub> renders the contrast between N and NC<sub>1</sub> insufficiently distinct.

(7) FQUALITY (S<sub>2</sub>-ALL) violated in [NC<sub>1</sub>VNC<sub>2</sub>] vs. [N<sub>1</sub>̃VNC<sub>2</sub>]

- a. NC<sub>1</sub>

V	̃V
---	----

 NC<sub>2</sub>
- b. N<sub>1</sub>

̃V
----

 NC<sub>2</sub>

A question arises at this point. If anticipatory nasalization from NC<sub>2</sub> is what reduces cues to the N–NC<sub>1</sub> contrast, why don't speakers just avoid nasalizing the pre-NC<sub>2</sub> vowel? A potential answer is that while reducing the amount of nasalization in the intervening vowel would enhance cues to the N–NC<sub>1</sub> contrast, it would also reduce cues to the contrast between NC<sub>2</sub> and a plain oral consonant, C. As discussed in Chapter 2, the nasal vs. oral quality of a preceding segment (or  $\Delta$  *formant quality (preceding segment)*,  $\Delta$  *formant quality* (S<sub>1</sub>)) is likely an important cue to the contrast between Cs and NCs. Beddor & Onsuwan (2003) have shown that, for Ikalanga speakers, rates of identification for voiced Cs (Ds) and NDs are highest if D is preceded by an oral vowel and ND is preceded by a nasal vowel. Thus while reducing the amount of nasal coarticulation in the vowel between the two NCs would enhance the cues to N–NC<sub>1</sub> (compare (8a) and (8b)), this enhancement would come at the expense of reducing the cues to C–NC<sub>2</sub> (compare (8a) and (8c)).

(8) Enhancing cues to N–NC<sub>1</sub> reduces cues to C–NC<sub>2</sub>

- a. NC<sub>1</sub>

V	→	̃V
---	---	----

 NC<sub>2</sub>
- b. N<sub>1</sub>

̃V
----

 NC<sub>2</sub>
- c. NC<sub>1</sub>

V
---

 C<sub>2</sub>

As shown above, in NC<sub>1</sub>VNC<sub>2</sub> sequences, considerations of contrast distinctiveness conflict: it is impossible to simultaneously render NC<sub>1</sub> maximally distinct from N, and NC<sub>2</sub> distinct from C. Making the simplifying assumption that Cs must be preceded by fully oral vowels and NCs must be preceded by fully nasal vowels for the contrast between them to be sufficiently distinct ((9); for other uses of  $\Delta$  FQUALITY (S<sub>1</sub>), see Chapter 2), this conflict can be formalized as in (10). Note that in (10) I also include the faithfulness constraint IDENT(VNas), which penalizes changes in the duration of nasal coarticulation (in (10), some vs. none) from the Realized Input to the output.

(9) MINDIST C–NC ( $\Delta$  FQUALITY (S<sub>1</sub>-ALL)): assign one violation for every C–NC pair in the input that does not differ in the oral vs. nasal quality of the preceding segment, such that:

- a. C is preceded by a segment that, from its beginning to its end, is marked by oral formants; and
- b. NC is preceded by a segment that, from its beginning to its end, is marked by nasal formants.

(10) NC<sub>1</sub>VNC<sub>2</sub> violates multiple distinctiveness constraints

NC <sub>1</sub> ṼNC <sub>2</sub>	NC <sub>1</sub> VC <sub>2</sub>	N <sub>1</sub> ̃VNC <sub>2</sub>	$\Delta$ FQ (S <sub>2</sub> -ALL)	$\Delta$ FQ (S <sub>1</sub> -ALL)	ID(VNas)
a. NC <sub>1</sub> ṼNC <sub>2</sub>	NC <sub>1</sub> VC <sub>2</sub>	N <sub>1</sub> ̃VNC <sub>2</sub>	*	*	
b. NC <sub>1</sub> ̃VNC <sub>2</sub>	NC <sub>1</sub> VC <sub>2</sub>	N <sub>1</sub> ̃VNC <sub>2</sub>	*		*
c. NC <sub>1</sub> VNC <sub>2</sub>	NC <sub>1</sub> VC <sub>2</sub>	N <sub>1</sub> ̃VNC <sub>2</sub>		*	*

Candidate (10a), in which  $NC_1V\tilde{V}NC_2$  is fully faithful to the Realized Input, incurs a violation of both distinctiveness constraints. It violates  $\Delta$  FQUALITY ( $S_2$ -ALL), as the nasality in the intervening vowel renders  $NC_1V\tilde{V}NC_2$  insufficiently distinct from  $N_1\tilde{V}NC_2$ ; it violates  $\Delta$  FQUALITY ( $S_1$ -ALL), as the orality in the intervening vowel renders  $NC_1V\tilde{V}NC_2$  insufficiently distinct from  $NC_1VC_2$ . In candidate (10b), full nasalization of the intervening vowel renders  $NC_1\tilde{V}NC_2$  sufficiently distinct from  $NC_1VC_2$ , but insufficiently distinct from  $N_1\tilde{V}NC_2$ . In candidate (10c), full oralization of the intervening vowel renders  $NC_1VNC_2$  sufficiently distinct from  $N_1\tilde{V}NC_2$ , but insufficiently distinct from  $NC_1VC_2$ . Note that (10b–c), where  $NC_1VNC_2$  is not faithful to the degree of nasal coarticulation present in the Realized Input, also both incur violations of IDENT(VNas).

The point here is that, in  $NC_1VNC_2$ , it is impossible to simultaneously satisfy both  $\Delta$  FQUALITY ( $S_2$ -ALL) and  $\Delta$  FQUALITY ( $S_1$ -ALL) without modification of  $NC_1VNC_2$ .

## 4.2.2 Choosing the repair

When faced with the perceptually sub-optimal sequence  $NC_1VNC_2$ , what does a language do? If it is a language in which all faithfulness constraints dominate both  $\Delta$  FQUALITY ( $S_2$ -ALL) and  $\Delta$  FQUALITY ( $S_1$ -ALL), then  $NC_1VNC_2$  will surface faithfully, as being faithful to the Realized Input is more important than maximizing the distinctiveness of the N–NC and C–NC contrasts. But within the class of languages where the opposite holds – where both of the  $\Delta$  FQUALITY constraints dominates some (or all) faithfulness constraints – whether nasalization or oralization is the preferred repair depends on the relative ranking of MAX(NasalC) (11a) and MAX(OralC) (11b).

- (11) Faithfulness constraints for nasal cluster effects
- MAX(NasalC): Assign one violation for each input [+nasal] consonant that lacks an output correspondent.
  - MAX(OralC): Assign one violation for each input [–nasal] consonant that lacks an output correspondent.

If  $MAX(NasalC) \gg MAX(OralC)$ , nasalization is the preferred repair, as deleting a [–nasal] consonant is preferable to deleting a [+nasal] consonant. If the reverse holds, and  $MAX(OralC) \gg MAX(NasalC)$ , oralization is the preferred repair, as deleting a [+nasal] consonant is preferable to deleting a [–nasal] consonant.

- (12)  $MAX(NasalC) \gg MAX(OralC)$  prefers nasalization

	NC	MAX(NasalC)	MAX(OralC)
a.	N		*
b.	C	*!	

- (13)  $MAX(OralC) \gg MAX(NasalC)$  prefers oralization

	NC	MAX(OralC)	MAX(NasalC)
a.	N	*!	
b.	C		*

Recall that, in almost all systems where nasalization is the preferred repair,  $NC_1$  is targeted (i.e.  $NC_1VNC_2 \rightarrow N_1VNC_2$ ).<sup>4</sup> This preference for  $NC_1$  nasalization follows naturally from a contrast-based analysis of nasal cluster effects, as  $NC_2$  nasalization does not fully solve the perceptual problem posed by  $NC_1VNC_2$ . If  $NC_1VNC_2$  is mapped to  $NC_1VN_2(V)$ , the intermediate vowel will still

<sup>4</sup>The one case of  $NC_2$  nasalization, in the western dialects of Gurindji (McConvell 1988), is discussed in section 4.3.1).

be nasalized to some degree as Ns, like NCs, induce anticipatory nasal coarticulation in many of the world's languages (see section 4.3.1 for discussion, also Chapter 3). Because NC<sub>2</sub> nasalization would not eliminate the coarticulatory vowel nasalization, this repair would incur a violation of both MAX(OralC) and  $\Delta$  FQUALITY (S<sub>2</sub>-ALL). Thus given the current constraint set and phonetic assumptions, NC<sub>2</sub> nasalization is harmonically bounded ((14); I revisit this point in section 4.3.1).

Although violations of IDENT(VNas) are not assessed in (14), I assume that IDENT(VNas) is violated when the repair is either NC<sub>1</sub> nasalization or NC<sub>2</sub> oralization. As shown in candidate (14b), I assume that NC<sub>2</sub> oralization results in a fully oral intervening vowel; as shown in candidate (14c), I assume that NC<sub>1</sub> nasalization results in a fully nasal intervening vowel. Candidates that retain the intermediate amount of nasalization are presumably ruled out by high-ranked constraints: the markedness constraint that prefers N<sub>1</sub>  $\tilde{V}$ NC<sub>2</sub> (to \*N<sub>1</sub>  $\tilde{V}$ NC<sub>2</sub>), for example, could be a constraint on articulatory effort, banning the quick succession of velum movements that would be necessary to produce an oral vowel in between two nasal consonants (\*NVN). The constraint that prefers NC<sub>1</sub>VC<sub>2</sub> (over \*NC<sub>1</sub>  $\tilde{V}$ C<sub>2</sub>) is  $\Delta$  FQUALITY (S<sub>2</sub>-ALL): the mapping from NC<sub>1</sub>  $\tilde{V}$ NC<sub>2</sub> to NC<sub>1</sub>  $\tilde{V}$ C<sub>2</sub> incurs a violation of MAX(NasalC) but does not satisfy  $\Delta$  FQUALITY (S<sub>2</sub>-ALL) (a candidate including NC<sub>1</sub>  $\tilde{V}$ C<sub>2</sub> would thus be harmonically bounded by (14b)).<sup>5</sup>

To simplify the presentation of the analysis, in (14) and all tableaux that follow, I omit reference to  $\Delta$  FQUALITY (S<sub>1</sub>-ALL) and candidate sets that violate it. This is akin to a claim that, in languages that eliminate NC<sub>1</sub>VNC<sub>2</sub> through deletion of a consonant, they do so because maintaining a maximally distinct C–NC<sub>2</sub> contrast is a top priority.

(14) NC<sub>2</sub> nasalization is harmonically bounded

	NC <sub>1</sub> $\tilde{V}$ NC <sub>2</sub> N <sub>1</sub> $\tilde{V}$ NC <sub>2</sub>	$\Delta$ FQ (S <sub>2</sub> -ALL)	MAX(NasalC)	MAX(OralC)
a.	NC <sub>1</sub> $\tilde{V}$ NC <sub>2</sub> N <sub>1</sub> $\tilde{V}$ NC <sub>2</sub>	*!		
b.	NC <sub>1</sub> VC <sub>2</sub> N <sub>1</sub> $\tilde{V}$ NC <sub>2</sub>		*!	
c.	N <sub>1</sub> $\tilde{V}$ NC <sub>2</sub> N <sub>1</sub> $\tilde{V}$ NC <sub>2</sub>			*
d.	NC <sub>1</sub> $\tilde{V}$ N <sub>2</sub> N <sub>1</sub> $\tilde{V}$ NC <sub>2</sub>	*!		*

Candidate (14a), the fully faithful candidate, is eliminated by a violation of  $\Delta$  FQUALITY (S<sub>2</sub>-ALL), because the vowel following NC is not fully oral. Candidate (14b), which displays NC<sub>2</sub> oralization, is eliminated by a violation of MAX(NasalC). Candidate (14c), which displays NC<sub>1</sub> nasalization, is the optimal candidate, as it violates only MAX(OralC). Candidate (14d), which displays NC<sub>2</sub> nasalization, is harmonically bounded by both (14a) and (14c). Thus the dispreference for NC<sub>2</sub> nasalization likely stems from the fact that it does not fully resolve the perceptual problem posed by NC<sub>1</sub>VNC<sub>2</sub>. It is important to note, however, that this result only holds given the current assumptions about both the constraint set and about phonetic implementation. I return to this point in section 4.3.1, where I show that the contrast-based account correctly predicts that NC<sub>2</sub> nasalization should exist (*contra* Jones 2000), but only if a number of specific conditions are met.

For the most part, the decision between NC<sub>1</sub> and NC<sub>2</sub> oralization is determined by independent

<sup>5</sup>Note that, by assuming that the extent of coarticulatory nasalization is regulated by the phonotactic component of the grammar, there is some duplication between the phonetic realization and the phonotactic components of the grammar. It is worth noting, however, that there are cases in which deletion of a nasal or an oral consonant can induce a mismatch between the nasality of a consonant and a vowel that precedes/follows it. For example: in Sea Dayak, NCs are in free variation with Ns. Vowels following underlying NCs, however, are always oral – regardless of whether /NC/ is realized as [NC] or [N] (e.g. [nāŋga? ~ nāŋa?] ‘set up a ladder’, Mielke et al. 2003:123). Assuming that phonotactic constraints are evaluated over a phonetically realized input allows us to easily explain this apparent case of opacity: even in cases where the oral component of NC goes missing, high-ranked IDENT(VNas) requires preservation of the vocalic orality following NC in the realized input, prohibiting the newly prevocalic N from inducing nasal coarticulation of its own.

morphological facts about the language (this point anticipated by Jones 2000). If MAX(OralC)  $\gg$  MAX(NasalC), and NC<sub>2</sub> is part of a suffix, we find NC<sub>2</sub> oralization (15); if this same ranking holds and NC<sub>1</sub> is part of a prefix, we find NC<sub>1</sub> oralization (16).

(15) NC<sub>2</sub> oralization in Gurindji (McConvell 1988:138 )

- a. /kaŋju+mpal/ → [kaŋju+pal] ‘across below’  
(cf. [kajira-mpal] ‘across the north’)
- b. /kanka+mpa/ → [kanka-pa] ‘upstream’  
(cf. [kani-mpa] ‘downstream’)

(16) NC<sub>1</sub> oralization in Timugon Murut (Blust 2012:367)

- a. /maN-tumbuk/ → [ma-tumbuk] ‘thump’  
(cf. [man-tutu] ‘pound’)
- b. /saN-gonggom/ → [so-gonggom] ‘one fistful’  
(cf. [son-dopo] ‘one fathom’)

What we see above is a specific instantiation of a well-known generalization: faithfulness to root material is prized over faithfulness to affixal material (e.g. McCarthy & Prince 1995, Beckman 1998). In both (15) and (16), affixal nasals are deleted, while root nasals are preserved. To derive this result, we can employ a positional faithfulness constraint (Beckman 1998) that penalizes deletion of [+nasal] consonants within the root domain (17).

(17) MAX(NasalC)-ROOT: Assign one violation if an input [+nasal] consonant in the root does not have an output correspondent.

Having MAX(NasalC)-ROOT in the system is sufficient to derive the attested directionality. In suffixing languages, NC<sub>2</sub> oralization is the preferred option as the alternative, NC<sub>1</sub> oralization, fatally violates MAX(NasalC)-ROOT (18). In cases where NC<sub>1</sub>VNC<sub>2</sub> spans a prefix-root boundary, NC<sub>1</sub> oralization is the preferred repair as the alternative, NC<sub>2</sub> oralization, fatally violates MAX(NasalC)-ROOT (19). (Note that in the model assumed here (Flemming 2008b), where faithfulness constraints are assessed against fully phonetically specified inputs, NC<sub>1</sub> and NC<sub>2</sub> oralization are not necessarily the repairs one would expect to find to NC<sub>1</sub>VNC<sub>2</sub>. Oralization entails both the loss of a consonant and a loss of nasality on a neighboring vowel, resulting in a more salient, and therefore less faithful change (Steriade 2001) than is induced by NC<sub>1</sub> nasalization. The analysis below thus amounts to a claim that the desire to preserve certain featural values can take priority over P-map faithfulness.)

(18) NC<sub>2</sub> oralization in suffixes (e.g. Gurindji, (15))

	NCV <sup><math>\tilde{V}</math></sup> <sub>Rt</sub> -NC	N <sup><math>\tilde{V}</math></sup> <sub>Rt</sub> -NC	$\Delta$ FQ (S <sub>2</sub> -ALL)	MAX(NasC)-RT	MAX(NasC)
a.	NCV <sup><math>\tilde{V}</math></sup> <sub>Rt</sub> -NC	N <sup><math>\tilde{V}</math></sup> <sub>Rt</sub> -NC	*!		
b.	CV <sup><math>\tilde{V}</math></sup> <sub>Rt</sub> -NC	N <sup><math>\tilde{V}</math></sup> <sub>Rt</sub> -NC		*!	
c.	NCV <sub>Rt</sub> -C	N <sup><math>\tilde{V}</math></sup> <sub>Rt</sub> -NC			*

(19) NC<sub>1</sub> oralization in prefixes (e.g. Timugon Murut, (16))

	NCV <sup><math>\tilde{V}</math></sup> -NC <sub>Rt</sub>	N <sup><math>\tilde{V}</math></sup> -NC <sub>Rt</sub>	$\Delta$ FQ (S <sub>2</sub> -ALL)	MAX(NasC)-RT	MAX(NasC)
a.	NCV <sup><math>\tilde{V}</math></sup> -NC <sub>Rt</sub>	N <sup><math>\tilde{V}</math></sup> -NC <sub>Rt</sub>	*!		
b.	CV <sup><math>\tilde{V}</math></sup> -NC <sub>Rt</sub>	N <sup><math>\tilde{V}</math></sup> -NC <sub>Rt</sub>			*
c.	NCV-C <sub>Rt</sub>	N <sup><math>\tilde{V}</math></sup> -NC <sub>Rt</sub>		*!	

Note that this analysis predicts the possibility of a language where the repair exhibited to NC<sub>1</sub>VNC<sub>2</sub> depends on morphological context: for example, a language might prefer NC<sub>1</sub> oralization for pre-

fixed forms, but NC<sub>2</sub> oralization for suffixed forms. This prediction is borne out in Mori Bawah, an Austronesian language of Indonesia (Esser & Mead 2011:18–20, also Blust 2012), where the choice of repair depends on the word’s morphological structure. If NC<sub>1</sub> VNC<sub>2</sub> crosses a prefix-stem boundary, NC<sub>1</sub> (part of the prefix) deletes (20a); if NC<sub>1</sub> VNC<sub>2</sub> crosses a stem-suffix boundary, NC<sub>2</sub> (part of the suffix) deletes (20b). When both NCs are contained in the prefixal domain, Esser & Mead (2011:19) claim that it is “usually the first [N] which is omitted”, but that on occasion the second N is omitted (20c). The Mori Bawah pattern can be analyzed as involving a preference for N<sub>1</sub> modification, which can be overridden by a preference to modify affixal over root material (as in (20b)) and a preference for each morpheme to have some phonological exponent (as in (20c)).

- (20) Morphology influences choice of repair in Mori Bawah (Esser & Mead 2011:18–20)
- a. *N<sub>2</sub> in stem, N<sub>1</sub> deletes:* /moN-pumpu/ → [mo-pumpu] ‘collect’
  - b. *N<sub>2</sub> in suffix, N<sub>2</sub> deletes:* /bonde-ŋku/ → [bonde-ku] ‘my rice field’
  - c. *N<sub>1</sub> is morpheme, N<sub>2</sub> deletes:* /m-poN-kaa/ → [m-po-kaa], PL-TRI-eat, (‘they eat’)

In most cases, then, the choice between NC<sub>1</sub> and NC<sub>2</sub> oralization is predictable given independent morphological facts about the language. But there are a small number of additional cases where there appears to be a default option, regardless of context or facts about the language’s morphology. In Mori Bawah, when both NCs are prefixal, the claim is that NC<sub>1</sub> is the preferred target of oralization; in Kwanyama and other Bantu languages, NC<sub>2</sub> oralization historically targeted nasal consonants inside the stem domain (21).

- (21) NC<sub>2</sub> oralization in Kwanyama (Herbert 1977:344)
- a. *ongadu* ‘crocodile’ (cf. Herero *ongandu*)
  - b. *ombabi* ‘steenbuck’ (cf. Herero *ombambi*)

It is unclear what to say about these cases, for a couple of reasons. First, all patterns like (21) in which NC<sub>2</sub> oralization applies regardless of morphological context are very likely unproductive, so there is a question as to whether any synchronic analysis of these facts is the correct one. Second, it is unclear what kind of constraint could drive directionality irrespective of morphological structure: why should oralization of NC<sub>1</sub> be preferred over oralization of NC<sub>2</sub>, or vice versa?

### 4.3 Asymmetries in repaired sequences

The section above has discussed the motivation for nasal cluster effects under a contrast-based approach, and shown how a contrast-based analysis can analyze some of the attested repairs to NC<sub>1</sub> VNC<sub>2</sub>. In this section, I turn to asymmetries in the typology of repairs, and show that several well-documented phonetic asymmetries correctly predict a set of implicational generalizations regarding the types of NC<sub>1</sub> VNC<sub>2</sub> sequences that are repaired.

#### 4.3.1 Asymmetries in the extent of nasal coarticulation

Recall that the MINDIST constraint introduced in (5),  $\Delta$  FQUALITY (S<sub>2</sub>-ALL), claims that N must be followed by a fully nasal segment, and NC by a fully oral segment, for the N–NC contrast to be sufficiently distinct. In this subsection, we will acknowledge the more realistic possibility that not all languages impose such a strict requirement. For example, a language might require N to be followed by a segment that is only half-nasal, and NC by a segment that is only half-oral, for N–NC to be sufficiently distinct. Assuming that all segments have a total duration of 100 durational units

(this assumption will be revisited later), we can state this requirement as a MINDIST constraint,  $\Delta$  FQUALITY (S<sub>2</sub>-50) (22):

- (22) MINDIST N-NC ( $\Delta$  FQUALITY (S<sub>2</sub>-50)): assign one violation for every N-NC pair in the output that does not differ in the nasal vs. oral quality of the following segment, such that:
- N is followed by a segment that, from its beginning to 50 durational units, is marked by nasal formants; and
  - NC is followed by a segment that, from its beginning to 50 durational units, is marked by oral formants.

Depending on the amount of nasalization in an intervening vowel, the contrast between NC<sub>1</sub>VNC<sub>2</sub> and N<sub>1</sub>VNC<sub>2</sub> may or may not satisfy  $\Delta$  FQUALITY (S<sub>2</sub>-50). The pair of representations in (23), for example, violates  $\Delta$  FQUALITY (S<sub>2</sub>-50), as the vowel intervening between the two NCs in (23a) is only 25 units oral. The pair of representations in (24), however, satisfies  $\Delta$  FQUALITY (S<sub>2</sub>-50), as the vowel intervening between the two NCs in (24a) is 50 units oral.

- (23) NC<sub>1</sub>VNC<sub>2</sub> where V is 25 units oral: violates  $\Delta$  FQUALITY (S<sub>2</sub>-50)

- NC<sub>1</sub>

V <sub>25</sub>	$\tilde{V}_{75}$
-----------------	------------------

 NC<sub>2</sub>
- N<sub>1</sub>

$\tilde{V}_{100}$
-------------------

 NC<sub>2</sub>

- (24) NC<sub>1</sub>VNC<sub>2</sub> where V is 50 units oral: satisfies  $\Delta$  FQUALITY (S<sub>2</sub>-50)

- NC<sub>1</sub>

V <sub>50</sub>	$\tilde{V}_{50}$
-----------------	------------------

 NC<sub>2</sub>
- N<sub>1</sub>

$\tilde{V}_{100}$
-------------------

 NC<sub>2</sub>

In a language where  $\Delta$  FQUALITY (S<sub>2</sub>-50) is undominated, we would expect only the pair of representations in (23) to be modified at the expense of faithfulness constraints (25). As the pair of representations in (24) satisfies  $\Delta$  FQUALITY (S<sub>2</sub>-50), no modification is necessary (26). In the tableaux below, the subscripted number stands for the amount of the vowel that is oral: so V<sub>50</sub> $\tilde{V}$  stands for a vowel that is 50 units oral and 50 units nasal, V<sub>25</sub> $\tilde{V}$  for a vowel that is 25 units oral and 75 units nasal. Below, I use FAITH as a cover constraint for the faithfulness constraints that prevent modification of NC<sub>1</sub>VNC<sub>2</sub>. The repair, NC<sub>1</sub> nasalization (in (25–26b)), was chosen arbitrarily.

- (25)  $\Delta$  FQUALITY (S<sub>2</sub>-50) violated, NCV<sub>25</sub> $\tilde{V}$ NC modified

	NCV <sub>25</sub> $\tilde{V}$ NC N $\tilde{V}$ NC	$\Delta$ FQUALITY (S <sub>2</sub> -50)	FAITH
a.	NCV <sub>25</sub> $\tilde{V}$ NC N $\tilde{V}$ NC	*!	
b.	N $\tilde{V}$ NC N $\tilde{V}$ NC		*

- (26)  $\Delta$  FQUALITY (S<sub>2</sub>-50) satisfied, NCV<sub>50</sub> $\tilde{V}$ NC not modified

	NCV <sub>50</sub> $\tilde{V}$ NC N $\tilde{V}$ NC	$\Delta$ FQUALITY (S <sub>2</sub> -50)	FAITH
a.	NCV <sub>50</sub> $\tilde{V}$ NC N $\tilde{V}$ NC		
b.	N $\tilde{V}$ NC N $\tilde{V}$ NC		*!

Note that modification of the pair of representations in (24) asymmetrically implies modification of the pair of representations in (23). A strict MINDIST constraint, like  $\Delta$  FQUALITY (S<sub>2</sub>-ALL), penalizes both (23) and (24): if  $\Delta$  FQUALITY (S<sub>2</sub>-ALL) is high-ranked, it will motivate modifi-



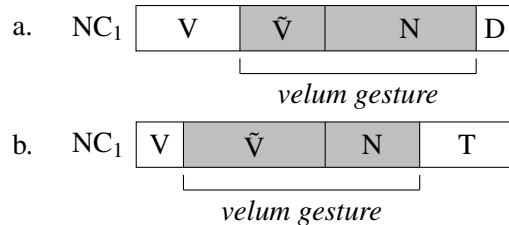
cation of both. A less strict MINDIST constraint, like  $\Delta$  FQUALITY ( $S_2$ -50), penalizes only (23): if  $\Delta$  FQUALITY ( $S_2$ -50) is high-ranked, it will only motivate modification of (23). No MINDIST constraint, however, can penalize only (24), as it is impossible to define a MINDIST constraint that penalizes more distinct contrasts to the exclusions of less distinct ones.

This predicted asymmetry is important because, within a language, some nasal consonants induce more nasal coarticulation than others. For example, when there is an asymmetry, languages exhibit temporally more extensive nasal coarticulation before coda (or non-prevocalic) nasals than they do before onset (or prevocalic) nasals (e.g. Schourup 1973; see also the discussion in Chapter 3). If a language employs a less restrictive MINDIST constraint, like  $\Delta$  FQUALITY ( $S_2$ -50), we might expect to find these phonetic asymmetries reflected in the typology. Repairs to  $NC_1VNC_2$  where the intervening vowel is less nasalized should asymmetrically imply repairs where the intervening vowel is more nasalized. As discussed below, this prediction is correct.

### Voicing in NC clusters

Cross-linguistically, the nasal portion of voiceless NC (NT) clusters is shorter than the nasal portion of voiced NC (ND) clusters. While N takes up the large majority of the time allotted to ND, for NT the time is more or less equally divided between N and T. For phonetic data from a variety of languages, see e.g. Maddieson & Ladefoged (1993), Ladefoged & Maddieson (1996: 4.3), Riehl (2008), Coetzee & Pretorius (2010), Cohn & Riehl (2012), and discussion in Chapter 2 of this study. But although the duration of the nasal consonant varies according to the overall duration of the NC sequence, the overall duration of the velum opening gesture appears to remain constant: N's duration is inversely correlated with the amount of anticipatory nasal coarticulation that it induces. Short Ns induce more; long Ns induce less. See Beddor (2009:789-795) for results demonstrating that this holds true for speakers of American English (also Cohn 1990); for evidence from other systems see Beddor (2009:788). For our purposes, what is important is that we expect to find more nasalization pre-NT (where N is shorter) than we do pre-ND (where N is longer) (27).

(27) Inverse correlation between N duration and extent of nasal coarticulation



We might expect, then, for the voicing of  $NC_2$  to have an effect on the relative distinctiveness of the N- $NC_1$  contrast. In (27a), the post- $NC_1$  vowel is less nasalized than it is in (27b). So N- $NC_1$  should be more distinct when  $NC_2$  is voiced than it is when  $NC_2$  is voiceless.

This asymmetry leads to a typological prediction. If a language repairs  $NC_1VND_2$  in response to a MINDIST violation (a context where cues to the N- $NC_1$  contrast are expected to be stronger), this asymmetrically implies that the language should also repair  $NC_1VNT_2$  (a context where cues to the N- $NC_1$  contrast are expected to be weaker). This prediction is hard to assess: in most descriptions, the role of  $NC_2$  voicing in nasal cluster effects is not discussed. In Mori Bawah (Blust 2012:367-370, also Esser & Mead 2011), however, there is an asymmetry in the predicted direction:  $NC_1VNT_2$  is repaired, but  $NC_1VND_2$  is not (28). Assuming that NTs induce more anticipatory nasalization in Mori Bawah than do NDs, (28) provides one example of a system in which only the

more endangered N–NC<sub>1</sub> contrasts are neutralized.<sup>6</sup>

(28) NC<sub>1</sub> oralization in Mori Bawah (data from Blust 2012:369)

- a. Triggered by NT<sub>2</sub>
  - (i) /moN-soŋka/ → [mo-soŋka] ‘arrange’
  - (ii) /moN-tampele/ → [mo-tampele] ‘hit, smack’
- b. Not triggered by ND<sub>2</sub>
  - (i) /moN-sombu/ → [mon-sombu] ‘connect, join’
  - (ii) /moN-tonda/ → [mon-tonda] ‘follow’

### Vocalic context of N<sub>2</sub>

So far, we have focused our attention solely on repairs to NC<sub>1</sub>VNC<sub>2</sub>. The contrast-based analysis developed to explain why many languages ban these sequences, though, predicts that NC<sub>1</sub>VN<sub>2</sub>V should be dispreferred as well, as onset (or prevocalic) Ns also induce anticipatory nasalization.<sup>7</sup>

But this prediction comes with a caveat: N’s syllabic context influences the amount of nasalization that it induces. As discussed more fully in Chapter 3, it has been documented for many languages that onset Ns induce less nasality in a preceding vowel than do coda Ns. A survey of nasalization patterns compiled by Jeong (2012) documents this pattern for French and Modern Greek; Krakow (1993) documents it for American English; Herbert (1977) documents it for a number of languages, including Pashto, Malagasy, and Delaware; and Schourup (1973:191) concludes, on the basis of a large typological survey, that “in no language examined are vowels nasalized before prevocalic nasals when they are not also nasalized before all pre-consonantal and word-final nasals.” This means that most, if not all, languages exhibit the asymmetry schematized below: in NC<sub>1</sub>VN<sub>2</sub>(...) sequences, the intermediate vowel is more nasalized when N<sub>2</sub> is in coda position (29) than it is when N<sub>2</sub> is in onset position (30).

(29) Intervening vowel is more nasalized when N<sub>2</sub> is in coda position

- a. NC<sub>1</sub>

V <sub>25</sub>	<u>Ṽ<sub>75</sub></u>
-----------------	------------------------

 NC<sub>2</sub>
- b. N<sub>1</sub>

<u>Ṽ</u>
-----------

 NC<sub>2</sub>

(30) Intervening vowel is less nasalized when N<sub>2</sub> is in onset position

- a. NC<sub>1</sub>

V <sub>50</sub>	<u>Ṽ<sub>50</sub></u>
-----------------	------------------------

 N<sub>2</sub>V
- b. N<sub>1</sub>

<u>Ṽ</u>
-----------

 N<sub>2</sub>V

Given the asymmetry schematized above, we might expect N–NC<sub>1</sub> to be more distinct when N<sub>2</sub> is in onset position, as the intervening vowel is less nasalized when N<sub>2</sub> is in onset position (i.e. NC<sub>1</sub>VN<sub>2</sub>V) than it is when N<sub>2</sub> is in coda position (i.e. NC<sub>1</sub>VNC<sub>2</sub>). This asymmetry leads to a typological prediction: if a language repairs NC<sub>1</sub>VN<sub>2</sub>V, where N–NC<sub>1</sub> is expected to be more

<sup>6</sup>Interestingly, in Mori Bawah, voiced NCs cannot be created through morpheme concatenation: /moN-basa/, for example, is realized as [mo-basa] ‘read’ (see Blust 2012:368 for further examples. Mori Bawah thus appears to counterexemplify the claim that NTs are universally more marked than NDs (e.g. Pater 1999, cf. Hyman 2001).

<sup>7</sup>From this point onward, I will refer to syllabic positions, rather than vocalic contexts. This is not crucial, and the analyses could function equally well either way – this decision just allows the analyses in Chapters 3 and 4 to be internally consistent.

distinct, it must also repair  $NC_1 VNC_2$ , where  $N-NC_1$  is expected to be less distinct. As shown in (31), this prediction is almost completely correct. Of the 67 languages surveyed, 31 ban both  $NC_1 VNC_2$  and  $NC_1 VN_2 V$ , while 35 ban  $NC_1 VNC_2$  only.

(31) Contexts of nasal cluster effects (\* = sequences is banned, ✓ = sequence is permitted)

	* $NC_1 VN_2 V$	✓ $NC_1 VNC_2$
* $NC_1 VNC_2$	31	35
✓ $NC_1 VN_2 V$	1	<i>n.a.</i>

The one language that bans  $NC_1 VN_2 V$  only is Bolia (Niger-Congo; Mamet 1960, Meeussen 1963). In Bolia, however, this restriction is only visible when the plural morpheme /ɲ/ is realized as [ɲ] preceding a  $VNV$ -initial word. Further study of the language would be necessary to determine if there is an available analysis that can make sense of this apparent exception.

Notice that the phonetic asymmetry appealed to here – that coda (or non-prevocalic) nasals induce more anticipatory nasal coarticulation than do onset nasals – has now been shown to predict two distinct asymmetries regarding the distribution of NCs: repair of  $NC_1 VN_2 V$  implies repair of  $NC_1 VNC_2$  (this chapter), and shielding in the heterosyllabic anticipatory context ( $V]_{\sigma}N$ ) implies shielding in the tautosyllabic anticipatory context ( $VN]_{\sigma}$ ) (Chapter 3). These appear to be completely unrelated generalizations, from different empirical domains, but under the present analysis their existence can be traced to the same contextual asymmetry in anticipatory nasal coarticulation.

#### An aside: returning to $NC_2$ nasalization

We are now at a point where we can return to  $NC_2$  nasalization, and see how it might be derived in a contrast-based approach. To begin, consider a hypothetical system with the properties in (32).

(32) Properties of systems that could exhibit  $NC_2$  nasalization

- Vowels preceding coda nasals are 75 units nasal, while vowels preceding onset nasals are 50 units nasal.
- To be distinct from N, NC must be followed by a vowel that is at least 50 units oral (in other words,  $\Delta FQUALITY (S_2-50)$  is undominated).
- Deletion of root consonants is impossible ( $MAX(NasalC)-ROOT$  and  $MAX(OralC)-ROOT$  are undominated).
- Nasalization is preferable to oralization ( $MAX(NasalC) \gg MAX(OralC)$ ).

In a language with these properties, when  $NC_2$  is a member of a suffix,  $NC_2$  nasalization will be the optimal repair. This is illustrated in (33). The fully faithful (33a), in which the intervening vowel is 25 units oral and 75 units nasal, incurs a fatal violation of  $\Delta FQUALITY (S_2-50)$ . Candidate (33b), which exhibits  $NC_2$  oralization, incurs a fatal violation of  $MAX(NasalC)$ . The optimal candidate, then, is (33c): although  $NC_2$  nasalization does not entirely remove the vowel nasality following  $NC_1$ , it removes enough of it for  $\Delta FQUALITY (S_2-50)$  to be satisfied.<sup>8</sup> Note that candidates with  $NC_1$  nasalization and oralization are not considered below; I assume that a root-suffix boundary separates  $NC_1$  and  $NC_2$ , and these candidates are therefore eliminated by undominated  $MAX(NasalC)-ROOT$  and  $MAX(OralC)-ROOT$ .

<sup>8</sup>I assume that additional phonotactic constraints require vowels before prevocalic nasals to be less nasalized; this reduction of nasalization occurs at the expense of  $IDENT(VNas)$ . Here, as in several other places, this amounts to a claim that there is a significant amount of duplication between the phonetic realization and the phonotactic components of the grammar. Not only must the phonetic grammar derive the generalization that prevocalic nasals induce less anticipatory nasal coarticulation than do non-prevocalic nasals, but the phonotactic component of the grammar must enforce it.

(33) How to generate NC<sub>2</sub> nasalization

NCV <sub>25</sub> <sup>V</sup> NCV N <sup>~</sup> VNCV	Δ FQ (S <sub>2</sub> -50)	MAX(NasalC)	MAX(OralC)
a. NCV <sub>25</sub> <sup>V</sup> NCV N <sup>~</sup> VNCV	*!		
b. NCVCV N <sup>~</sup> VNCV		*!	
c. NCV <sub>50</sub> <sup>V</sup> NV N <sup>~</sup> VNCV			*

This situation is potentially attested. While Gurindji (McConvell 1988) is a language that generally exhibits NC<sub>2</sub> oralization, in some western dialects, NC<sub>2</sub> nasalization is reported instead (34).

(34) NC<sub>2</sub> nasalization in western Gurindji dialects (McConvell 1988:150)

- a. ɲumpin-ku → ɲumpin-ɲu (n.g.)
- b. nuŋkijɪŋ-ku → nuŋkijɪŋ-ɲu (n.g.)

McConvell (p. 150) writes that “this alternation [NC<sub>2</sub> nasalization] probably arose from a general phonetic tendency towards nasal assimilation in clusters in western dialects of Gurindji. . . Here this tendency has been adopted to remove some prominent violations of an apparent constraint against ‘adjacent’ occurrences of nasal clusters.” And as predicted by the contrast-based account, the western dialects of Gurindji do appear to have many, if not all, of the properties listed in (32): NC<sub>1</sub>VNC<sub>2</sub> but not NC<sub>1</sub>VN<sub>2</sub>V is repaired, suggesting that only N–NC<sub>1</sub> contrasts preceding coda nasals are insufficiently distinct; nasalization is apparently the preferred repair; and we know from other facts about the language that preservation of root material is important (for example, nasal cluster effects only target NC<sub>2</sub> when the NC sequence is in the suffixal domain; see McConvell 1988:144 for further discussion). It appears, then, that what we find in the western dialects of Gurindji is exactly what the contrast-based analysis predicts: under a very specific set of circumstances, NC<sub>2</sub> nasalization is the optimal repair.<sup>9</sup>

### 4.3.2 On the role of NC’s oral release

In the previous subsection, we saw that the syllabic context of N<sub>2</sub> can play a decisive role in determining whether or not nasal cluster effects are motivated. If nasal cluster effects are motivated by an onset N<sub>2</sub>, they are also motivated by a coda N<sub>2</sub>; if nasal cluster effects are motivated by an N<sub>2</sub> that precedes a voiceless stop, they are also motivated by an N<sub>2</sub> that precedes a voiced stop. In this subsection, we will see that the identity of NC<sub>1</sub> plays a crucial role as well.

The discussion up to this point has focused on the importance of external (or transitional) cues to the N–NC contrast (i.e. the relative amounts of nasalization following NCs in different segmental contexts), but internal cues (i.e. properties of the NCs themselves) play an important role as well. As discussed in Chapter 2, Beddor & Onsuwan (2003) have shown that, for Ikalanga speakers, an additional cue to the N–ND contrast is the presence of ND’s oral closure and release burst. As the oral portion of ND increases in duration and burst amplitude, listeners become less likely to identify it as N and more likely to identify it as ND. Extrapolating from this, we can infer that the longer and more salient the NC’s release, the greater Δ *burst* will be. As noted above, voiceless NCs (NTs) have a longer oral portion than do voiced NCs (NDs), and likely a more salient oral release (see Chapter 2). All else being equal, we might therefore expect Δ *burst* to be greater for N–NT ((35a)

<sup>9</sup>It is also possible that what we see in the western dialects of Gurindji is not in fact a true example of NC<sub>2</sub> nasalization. McConvell notes that NC nasalization is an *entirely general process* in these dialects, meaning that even in a word with just one NC, it is variably realized as N. This raises the possibility that the instances of NC<sub>2</sub> nasalization in (34) require no further explanation, but citing a tendency towards NC nasalization does not alone explain why this tendency is variable in words with one NC and apparently exceptionless in words with two.

vs. (35c)) than it is for N–ND ((35b) vs. (35c)), rendering N–NT more distinct than N–ND even when external cues to the contrast are compromised. (Notice that this fact, too, has already allowed us to explain aspects of the distributional properties of NCs: the greater distinctiveness of N–NT, as compared to N–ND, compels some languages to device NDs in word-final position where external cues to the contrast are absent. See Chapter 2 for discussion on this point.)

(35) N–NT is more distinct than N–ND

a.	N	T	V	$\tilde{V}_{75}$
b.	N	D	V	$\tilde{V}_{75}$
c.	N	$\tilde{V}_{100}$		

So far, the MINDIST constraints that have been introduced in this chapter refer only to the external cues to the N–NC contrast, i.e.  $\Delta$  *formant quality* ( $S_2$ ). To acknowledge the role of internal cues to the N–NC contrast, we can write a disjunctive MINDIST constraint, requiring the presence of one out of a number of cues (see Flemming 2002:57ff, also Chapter 2). For example, we could say that for the N–NC contrast to be sufficiently distinct, one satisfactory difference would be for the N–NC contrast to have a  $\Delta$  *burst* of 2, where N = 0, ND = 1, and NT = 2 (see also Chapter 2 for additional uses of this scale). Another satisfactory difference would be for the N–NC contrast to be marked by sufficient external cues, here 50 units of the appropriate nasal vs. oral formants, following both Ns and NCs. This disjunctive constraint, defined in (36), is similar to the MINDIST constraint proposed in Chapter 2 to account for final ND devoicing, in that it requires the presence of *either* a significant difference in  $\Delta$  *burst*, *or* the appropriate transitional cues, for N–NC to be sufficiently distinct. (36) differs from the similar constraint proposed in Chapter 2 only in that it is more explicit regarding what constitutes a sufficient duration of the appropriate formant quality.

- (36) MINDIST N–NC ( $\Delta$  BURST-2 or  $\Delta$  FQUALITY ( $S_2$ -50)): assign one violation for every N–NC pair in the output that does not differ in either (i)  $\Delta$  *burst* of 2 or (ii) the nasal vs. oral quality of the following segment, such that:
- N is followed by a segment that, from its beginning to 50 durational units, is marked by nasal formants; and
  - NC is followed by a segment that, from its beginning to 50 durational units, is marked by oral units.

The contrast between NTV<sub>25</sub> $\tilde{V}$ NC (35a) and N $\tilde{V}$ NC (35c) satisfies the constraint in (36): even though NT is not followed by a vowel that is 50 units oral, the internal cues are sufficient as  $\Delta$  *burst* = 2. But the contrast between NDV<sub>25</sub> $\tilde{V}$ NC (35b) and N $\tilde{V}$ NC (35c) does not satisfy the constraint in (36), as ND is not followed by a vowel that is at least 50 units oral and  $\Delta$  *burst* = 1.

If  $\Delta$  BURST-2 or  $\Delta$  FQUALITY ( $S_2$ -50) is undominated, assuming the phonetics in (35), we would expect ND<sub>1</sub>VNC<sub>2</sub> but not NT<sub>1</sub>VNC<sub>2</sub> to be modified. This is because N–NT<sub>1</sub> is sufficiently distinct when it is followed by a vowel that is only 25 units oral, but N–ND<sub>1</sub> is not.<sup>10</sup>

<sup>10</sup>This analysis also predicts the possibility that ND will devoice to NT in an ND<sub>1</sub>VNC<sub>2</sub> context, to keep N–NC<sub>1</sub> sufficiently distinct when external cues to the contrast are compromised. To the best of my knowledge, such a repair is unattested. Enhancement of an N–ND contrast through ND devoicing, though, is attested more generally; see Chapter 2.

(37) $\Delta$ BURST-2 or $\Delta$ FQUALITY ( $S_2$ -50) violated, $NDV_{25}\tilde{V}NC$ modified			
$NDV_{25}\tilde{V}NC$ $N\tilde{V}NC$		$\Delta$ BURST-2 or $\Delta$ FQUALITY ( $S_2$ -50)	FAITH
a. $NDV_{25}\tilde{V}NC$ $N\tilde{V}NC$		*!	
b. $N\tilde{V}NC$ $N\tilde{V}NC$			*
(38) $\Delta$ BURST-2 or $\Delta$ FQUALITY ( $S_2$ -50) satisfied, $NTV_{25}\tilde{V}NC$ not modified			
$NTV_{25}\tilde{V}NC$ $N\tilde{V}NC$		$\Delta$ BURST-2 or $\Delta$ FQUALITY ( $S_2$ -50)	FAITH
a. $NTV_{25}\tilde{V}NC$ $N\tilde{V}NC$			
b. $N\tilde{V}NC$ $N\tilde{V}NC$			*!

Under a contrast-based analysis, it is impossible to derive the opposite asymmetry. While it is possible to formulate a MINDIST constraint that can penalize both  $ND_1VNC_2$  and  $NT_1VNC_2$  (e.g.  $\Delta$  FQUALITY ( $S_2$ -ALL)), defined in (5)), as well as a MINDIST constraint that penalizes only  $ND_1VNC_2$ , it is impossible to formulate a MINDIST constraint that penalizes only the more distinct  $N-NC_1$  contrast in  $NT_1VNC_2$ . This makes a typological prediction: if a language repairs  $NT_1VNC_2$  in response to a MINDIST violation, this implies that it must also repair  $ND_1VNC_2$ .

This prediction is difficult to assess, for reasons that are completely consistent with the discussion above: there are not that many languages that ban  $NT_1VNC_2$ . For example, while  $NC_1$  nasalization consistently targets  $ND_1$  in Bantu, it has never targeted  $NT_1$ . Herbert (1977: 365) attributes this asymmetry to the facts discussed above: he notes that “in a post-nasal environment, the voiced stops evidence the most reduction and are therefore the most susceptible to nasalization. . . voiceless stops and fricatives are more distinctive in this environment.” In the small number of languages that do repair  $NT_1VNC_2$ , confounding factors prevent us from determining whether or not  $ND_1VNC_2$  would be repaired as well. In Gurindji (McConvell 1988) and other Australian languages in the survey, for example, obstruent voicing is not distinctive.

There is, however, some evidence from Ngaju Dayak (Blust 2012) that the duration or salience of  $NC_1$ ’s oral component plays a role in the motivation of nasal cluster effects. In Ngaju Dayak, the rate of application of  $NC_1$  nasalization varies according to  $NC_1$ ’s place of articulation. Table 4.1, adapted and simplified from Blust 2012:373, summarizes the success and failure rates of  $NC_1$  nasalization according to  $NC_1$ ’s place of articulation, as well as whether or not  $NC_1$  is expected to apply (Blust’s data come from Hardeland 1859, a Ngaju Dayak-German dictionary of approximately 8000 entries). Across all places of articulation, the difference between the rates of  $NC_1$  nasalization according to  $\underline{NCV}NC$  vs.  $\underline{NCV}CV$  context (i.e. whether or not there is a following NC) clearly demonstrates that  $NC_1$  nasalization is conditioned by the presence of a following NC. But even when expected,  $NC_1$  nasalization does not always apply. As is clear in Table , the rate of  $NC_1$  nasalization depends on  $NC_1$ ’s place of articulation: labial  $NC_1$  is the most likely to undergo  $NC_1$  nasalization, with velar  $NC_1$  less likely to undergo, and palatal  $NC_1$  even less likely. (While the alveolars appear to pattern between the velars and the palatals, it should be noted that the sample size for alveolars is extremely small: see Blust 2012:372, fn. 13 for discussion.)

Although this has not been specifically documented for Ngaju Dayak, a consistent cross-linguistic observation is that, the further back a stop’s place of articulation, the longer its VOT (Maddieson 1996, Cho & Ladefoged 1999). In Table 4.1, we find that the rate of  $NC_1$  nasalization is inversely correlated with this generalization. Stops that generally have shorter VOTs (i.e. bilabials) are more frequent targets; those that generally have longer VOTs (i.e. palatal affricates) are less frequent targets. Assuming that stops with longer VOTs (or more generally, more salient releases) are more distinct from nasals, the data in Table 4.1 are completely consistent with the predictions of

Table 4.1: NC<sub>1</sub>VNC<sub>2</sub> patterns in Ngaju Dayak

Is NC <sub>1</sub> nasalization expected?	Place of NC <sub>1</sub>	Does NC <sub>1</sub> nasalization apply?		
		Yes	No	Variable
Yes ( <u>NCV</u> NCV) No ( <u>NC</u> VCV)	Bilabial (mb <sub>1</sub> )	94% (63/67) 6% (9/159)	3% (2/67) 94% (150/159)	3% (2/67) —
Yes ( <u>NCV</u> NCV) No ( <u>NC</u> VCV)	Alveolar (nd <sub>1</sub> )	29% (2/7) 4% (3/75)	29% (2/7) 96% (72/75)	43% (3/7) —
Yes ( <u>NCV</u> NCV) No ( <u>NC</u> VCV)	Palatal (dʒ <sub>1</sub> )	15% (2/13) —	85% (11/13) 100% (89/89)	— —
Yes ( <u>NCV</u> NCV) No ( <u>NC</u> VCV)	Velar (ŋg <sub>1</sub> )	64% (16/25) 9% (10/114)	36% (9/25) 91% (104/114)	— —

a contrast-based account. Less distinct N–NC<sub>1</sub> contrasts (those where NC likely has a shorter VOT) are targeted more often by NC<sub>1</sub> nasalization; more distinct N–NC<sub>1</sub> contrasts (those where NC likely has a longer VOT) are targeted less often by NC<sub>1</sub> nasalization.<sup>11</sup> Note also that the failure of NC<sub>1</sub> nasalization to apply especially when NC<sub>1</sub> is an affricate has a direct parallel in Huave (Kim 2008), where affricated (but not plain) NCs are allowed word-finally. The analysis of these two systems is the same: when external cues to the N–NC contrast are compromised, those contrasts with the most robust internal cues are the most likely to survive.

### 4.3.3 The role of homorganicity

In some systems, nasal cluster effects only occur when one of NC<sub>1</sub> or NC<sub>2</sub> (which of these depending on the language) is homorganic. In Nhanda (Pama-Nyungan), for example, NC<sub>2</sub> oralization occurs when NC<sub>1</sub> is homorganic (39a), but does not occur when NC<sub>1</sub> is heterorganic (39b). The data below are from Blust (2012:376); see Blevins (2001) for the original description.

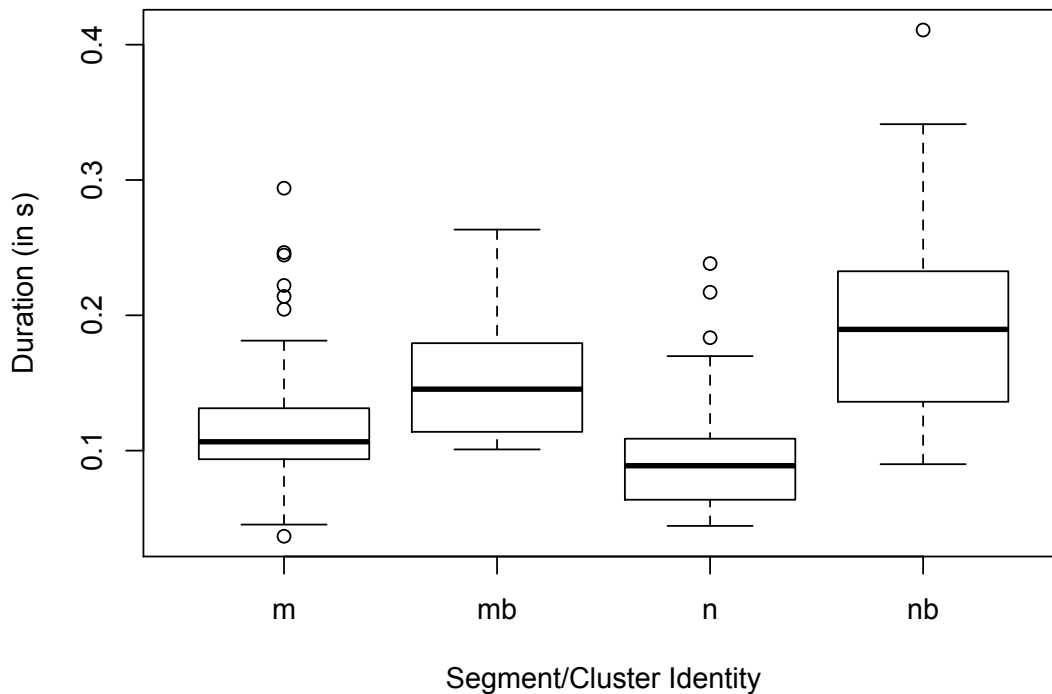
- (39) NC<sub>2</sub> oralization in Nhanda
- a. Occurs when NC<sub>1</sub> is homorganic
    - (i) minjdʒu-gu ‘purse-ERG’
    - (ii) wumba-gula ‘hide-AMB’
  - b. Does not occur when NC<sub>1</sub> is heterorganic
    - (i) thurnba-ŋgu ‘dove-ERG’
    - (ii) wujba-ŋgula ‘whistle-AMB’

It may be possible to make sense of this restriction if, in Nhanda, heterorganic NCs are longer than homorganic NCs. While recordings of Nhanda are not publicly available, a small pilot study of NC durations in five other Australian languages (Guguyimidjir, Pama-Nyungan; Gunwinggu, Arnhem; Murrinh-Patha, Southern Daly; Nyangumarta, Pama-Nyungan; and Yindjibarndi, Pama-Nyungan) indicates that this hypothesis is plausible. For each of these languages, I extracted tokens containing [mb] and [nb] from recordings available in the UCLA Phonetics Lab Archive; these clusters were

<sup>11</sup>In a number of Bantu languages, only velar NC<sub>1</sub> undergoes NC<sub>1</sub> nasalization; see Meeussen (1963). Without knowing more about the phonetics of velar NC clusters in these languages, it is hard to know what to make of this. Compounding this difficulty is the fact that NC<sub>1</sub> nasalization in most Bantu languages is unproductive, and the set of targets is often limited to a set of clusters whose phonetics have likely changed since the pattern ceased to be productive.

selected as they are relatively common across Australian languages. The number of tokens measured per language ranged from 13 to 18, summing 80 in total (46 [mb]s and 24 [nb]s). In addition, from each of the five languages I extracted 18 tokens containing [m] and 18 tokens containing [n], so as to confirm that any durational difference between [mb] and [nb] could not be traced to an inherent durational difference between [m] and [n]. In all tokens, the target sequence came in between the first two vowels in the word (so *kan**b**arr*, *kum**p**u*, *kana*, etc.). For [m] and [n], I measured the interval between the offset of V<sub>1</sub> and the onset of V<sub>2</sub>; for [mb] and [nb], I measured the interval between the offset of V<sub>1</sub> and the burst of the NC. The results are presented in Figure 4-1, which aggregates results across the five languages.

Figure 4-1: Durations of Ns and NCs in 5 Australian languages



As is evident from Figure 4-1, heterorganic [nb] is, on average, longer than homorganic [mb]. In addition, the fact that [nb] is longer than [mb] is not due to an intrinsic durational asymmetry between [n] and [m], as singleton [n] is *shorter* than singleton [m]. To assess whether or not these asymmetries were significant, I fit a linear mixed effects model to the data visualized in Figure 4-1 (using the `lmer` function of R's `lme` package; Bates & Maechler 2011), with fixed effects for the identity of the nasal and the length of the sequence, as well as random effects for language and lexical item. The model indicates that there is a main effect of nasal identity, such that [n] is associated with shorter durations than [m] ( $p < .01$ ); a main effect of sequence length, such that clusters are longer than segments ( $p < .001$ ); and a significant interaction between nasal identity and sequence length, indicating that the durational difference between segments and clusters is magnified for the [n] vs. [nb] comparison ( $p < .001$ ). (Significance values were calculated from F statistics using R's `lmerTest` package, Kuznetsova et al. 2016.) In short, the results of the pilot study are consistent with the hypothesis that heterorganic NC clusters are longer than homorganic NC clusters. For some evidence that this asymmetry holds more broadly, see Slis (1974) on Dutch.

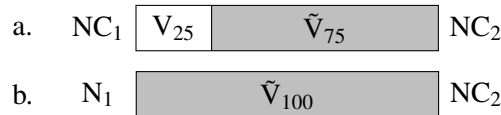


Why should it matter if heterorganic NCs are longer than homorganic NCs? While it is unclear how the extra duration afforded to heterorganic NC clusters is distributed between N and C,<sup>12</sup> one possibility is that things scale: the Cs in homorganic clusters are shorter than those in heterorganic clusters, and the Ns in homorganic clusters are shorter than those in heterorganic clusters (for some evidence that the latter part of this is true, see Fletcher et al. 2010 on Bininj Gun-wok.) If this is the case, then we can potentially say something about the role of homorganicity in triggering nasal cluster effects. If the Cs in homorganic NC clusters are shorter than the Cs in heterorganic NC clusters, then homorganic NC<sub>1</sub> might be less distinct from N than heterorganic NC<sub>1</sub> would be, as its internal cues (i.e. duration of the oral component) are less robust (see section 4.3.2). And if the Ns in homorganic NC<sub>2</sub> are shorter than the Cs in heterorganic NC clusters, then homorganic NC<sub>2</sub> might induce more anticipatory coarticulation than heterorganic NC<sub>2</sub>, and more greatly endanger the cues to N–NC<sub>1</sub> (see section 4.3.1). Given this, the homorganicity requirement has the same explanation as the rest of the asymmetries discussed in this section: nasal cluster effects are first observed in contexts where the N–NC<sub>1</sub> contrast is less distinct.

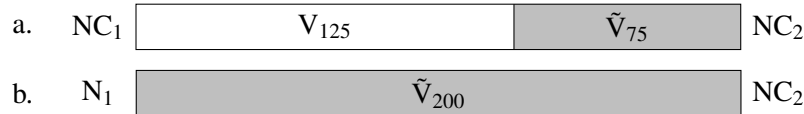
#### 4.3.4 The role of vowel length

The preceding discussion has focused entirely on how properties of NC<sub>1</sub> and NC<sub>2</sub> can affect the application of nasal cluster effects. The contrast-based approach also makes predictions about how properties of the intervening vowel should affect the application of nasal cluster effects; in this section, I will focus on the length of the intervening vowel. Assuming that the duration of anticipatory nasalization induced by a given nasal is fixed, regardless of the preceding vowel's duration (as was assumed throughout Chapter 3), the intervening vowel in NC<sub>1</sub>VNC<sub>2</sub> will be more nasalized than that in NC<sub>1</sub>V:NC<sub>2</sub>. Below, I assume that long vowels are twice as long as short vowels, but that regardless of the vowel's length, the temporal extent of nasalization induced by NC<sub>2</sub> is the same. We would therefore expect N–NC<sub>1</sub> to be less distinct in NC<sub>1</sub>VNC<sub>2</sub> when the intervening vowel is short (40), and more distinct in NC<sub>1</sub>VNC<sub>2</sub> when the intervening vowel is long (41).

(40) N–NC<sub>1</sub> is less distinct when the intervening vowels is short



(41) N–NC<sub>1</sub> is more distinct when the intervening vowel is long



This asymmetry leads to a typological prediction: if a language repairs NC<sub>1</sub>V:NC<sub>2</sub> (with a long intervening vowel), then it must also repair NC<sub>1</sub>VNC<sub>2</sub> (with a short intervening vowel). This is because while it is possible to formulate a strict MINDIST constraint that penalizes both N–NC<sub>1</sub> contrasts in (40–41) (e.g. Δ FQUALITY (S<sub>2</sub>-ALL)), or a less strict MINDIST constraint that penalizes only the less distinct N–NC<sub>1</sub> contrast in (40) (e.g. Δ FQUALITY (S<sub>2</sub>-50)), it is impossible to define a MINDIST constraint that penalizes only the more distinct N–NC<sub>1</sub> contrast in (41).

<sup>12</sup>In the pilot study described above I did not attempt to measure the relative contributions of N and C to NC duration, as in the available recordings there was no obvious break between the two components of the NC.

In the one case where the length of the intervening vowel appears to affect the application of nasal cluster effects, the asymmetry goes in the predicted direction: in Yindjibarndi (Pama-Nyungan, Wordick 1982), NC<sub>1</sub>VNC<sub>2</sub> but not NC<sub>1</sub>V:NC<sub>2</sub> is repaired through NC<sub>2</sub> oralization.<sup>13</sup> As demonstrated by the near-minimal pairs in (42), vowel length in Yindjibarndi is phonemically contrastive. Following Wordick, long vowels are transcribed as a sequence of two vowels; all page numbers for the examples in (42–48) are from Wordick (1982).

- (42) Vowel length contrast in Yindjibarndi
- a. *kaartu* ‘shout’ (p. 286)  
*karta* ‘lowness, bottom; coastal lowlands...’ (p. 292)
  - b. *ngaarta* ‘Aboriginal man; Aboriginal person’ (p. 315)  
*ngarta* ‘still, yet’ (p. 318)
  - c. *tyuurri* ‘pigtail, queue’ (p. 359)  
*tyurrawirn* ‘yellow-fronted honeyeater’ (p. 359)

As shown in (43), NC<sub>2</sub> oralization occurs when a single vowel – or a vowel followed by an approximant consonant – intervenes between a root and a suffixal NC. Elision of intervocalic /k/ to [w], and subsequent deletion of the [w] in certain vocalic contexts, can be observed in the data below. This process, while relevant to the full analysis, will not be discussed further here.

- (43) NC<sub>2</sub> oralization applies across short vowels
- a. *wuntu+ngka* → *wuntu-wa* ‘river-LOC’ (p. 33)  
(cf. *mutyi-ngka* ‘hole-LOC’ (p. 62))
  - b. *warnta+ngku* → *warnta-u* ‘stick-INST’ (p. 33)  
(cf. *mara-ngku* ‘hand-INST’ (p. 66))
  - c. *thangkarr+mpa* → *thangkarr-pa* ‘enough-TOPIC’ (p. 34)  
(cf. *nhaa-mpa* ‘this-TOPIC’ (p. 205))

But when a long vowel – or vowels separated by an intervening glide – intervenes between the two NCs, NC<sub>2</sub> oralization fails. The examples Wordick provides to support this claim are below (48).

- (44) NC<sub>2</sub> oralization does not apply across long vowels
- a. *ngaarnrtu+ku+mpa+rtu* → *ngaarnrtu-u-mpa-rtu* ‘my-??-TOP-??’ (p. 34)
  - b. *wuntu+ngka+mpa+rtu* → *wurntu-wa-mpa-rtu* ‘river-LOC-TOP-??’ (p. 34)

One interpretation of the examples in (43–48) is as previewed above: NC<sub>2</sub> oralization must apply when the intervening vowel is short, but it cannot apply when the intervening vowel is long. But it is important to note here that there is an alternative interpretation of the data available, in which the failure of NC<sub>2</sub> oralization to apply in (48) has more to do with the nature of the material that intervenes between the two NCs.

Let us assume, for the time being, that in Yindjibarndi, NC<sub>2</sub> oralization is capable of applying at an unbounded distance, across all segment types but stops. In other words, \*NC<sub>1</sub>...¬[-cont-son]...NC<sub>2</sub>, but ✓NC<sub>1</sub>...[-cont,-son]...NC<sub>2</sub>; see section 4.4 for discussion of a similar pattern in Gurindji (Pama-Nyungan, McConvell 1988). Let us further assume that NC<sub>2</sub> oralization and lenition/deletion are rules that apply in that order: lenition/deletion can apply to the output of NC<sub>2</sub> oralization, but NC<sub>2</sub> cannot apply to the output of lenition/deletion. With the assumption that stops

<sup>13</sup>NC<sub>2</sub> oralization is to some extent morphologically restricted: Wordick (p. 33) notes that it is “perhaps most noticeable in connection with the inflection for locative and instrumental case of disyllabic common nouns ending in a vowel.”

block NC<sub>2</sub> oralization in place, simply asserting that the two rules apply in this order derives the correct result (45). In the case of underlying *ngaarnrtu+ku+mpa+rtu*, for example, NC<sub>2</sub> oralization fails to apply due to the presence of an intervening /k/. Lenition and deletion then apply to *ngaarnrtu+ku+mpa+rtu*, yielding *ngaarnrtu+u+mpa+rtu*. Even though the environment necessary for NC<sub>2</sub> nasalization to apply is now available, it is too late: here, lenition/deletion counterfeeds NC<sub>2</sub> oralization. This ordering also derives the correct result for cases in which NC<sub>2</sub> oralization applies: as shown below, for forms like (43a), NC<sub>2</sub> oralization feeds lenition/deletion.

(45) Alternative, rule-ordering analysis for the Yindjibarndi data

	(48a)	(48b)	(43a)
Underlying Form	<i>ngaarnrtu+ku+mpa+rtu</i>	<i>wuntu+ngka+mpa+rtu</i>	<i>wuntu+ngka</i>
NC <sub>2</sub> oralization	–	<i>wuntu+ka+mpa+rtu</i>	<i>wuntu-ka</i>
Lenition/Deletion	<i>ngaarnrtu+u+mpa+rtu</i>	<i>wuntu+wa+mpa+rtu</i>	<i>wuntu-wa</i>
Surface Form	<i>ngaarnrtu+u+mpa+rtu</i>	<i>wuntu+wa+mpa+rtu</i>	<i>wuntu-wa</i>

These analyses make different predictions: the duration-based analysis predicts that NC<sub>1</sub>V:NC<sub>2</sub> should be permitted regardless of whether the long vowel is underlying or derived; the rule ordering analysis predicts that NC<sub>1</sub>V:NC<sub>2</sub> should be banned if the long vowel is underlying, but permitted if it is derived from a ...[+syllabic][–cont,–son][+syllabic]... sequence. As there are no examples provided in which the long vowel in NC<sub>1</sub>V:NC<sub>2</sub> is underlying, however (in both cases in (48) it is derived), these diverging predictions cannot be evaluated.

But whatever the correct analysis of the Yindjibarndi facts may be, the prediction outlined in this section regarding the length of the intervening vowel in NC<sub>1</sub>VNC<sub>2</sub> is not incorrect. While the one potential case in which NC<sub>1</sub>VNC<sub>2</sub> is repaired to the exclusion of NC<sub>1</sub>V:NC<sub>2</sub> is amenable to an alternative analysis, there are no cases where NC<sub>1</sub>V:NC<sub>2</sub> is repaired to the exclusion of NC<sub>1</sub>VNC<sub>2</sub>. This latter gap is what the contrast-based analysis predicts.

### 4.3.5 Comparison with an OCP-motivated analysis

In this section, we have seen that a contrast-based account of nasal cluster effects correctly predicts a number of implicational generalizations regarding the types of NC<sub>1</sub>VN<sub>2</sub>(...) sequences repaired. These generalizations are summarized in (46).

(46) Verified predictions of the contrast-based account

- Repair of NC<sub>1</sub>VND<sub>2</sub> implies repair of NC<sub>1</sub>VNT<sub>2</sub>.
- Repair of NC<sub>1</sub>VN<sub>2</sub>V implies repair of NC<sub>1</sub>VNC<sub>2</sub>.
- Repair of NT<sub>1</sub>VNC<sub>2</sub> implies repair of ND<sub>1</sub>VNC<sub>2</sub>.
- Repair of NC<sub>1</sub>V:NC<sub>2</sub> implies repair of NC<sub>1</sub>VNC<sub>2</sub>.

An OCP-motivated, dissimilation-style analysis of nasal cluster effects is capable of accounting for some of these generalizations: (46d), for example, is consistent with the generalization that dissimilatory processes can be restricted to apply in a set of local contexts, to the exclusions of all less local contexts. In Yimas (Foley 1991:54), for example, lateral dissimilation only applies if the offending segments are in adjacent syllables (see also e.g. Odden 1994, Suzuki 1998:84–87 for analysis). And even in systems where dissimilatory processes are capable of applying at unbounded distances, they tend to apply more regularly at shorter distances than they do at longer distances (e.g. Zymet 2014). Thus the fact that a language might ban NC<sub>1</sub>VNC<sub>2</sub> but permit NC<sub>1</sub>V:NC<sub>2</sub> is not surprising, under a dissimilation-style analysis.

Other generalizations identified above, however, cannot be predicted by an OCP-motivated analysis of nasal cluster effects, nor is it clear that such an account could account for them in a principled manner. The generalization in (46b) is particularly difficult: while the ban on NC<sub>1</sub>VNC<sub>2</sub> can plausibly be analyzed as an OCP effect, the ban on NC<sub>1</sub>VN<sub>2</sub>V cannot be. It would be difficult to explain, under an OCP-motivated analysis, why repair of NC<sub>1</sub>VN<sub>2</sub>V implies satisfaction of the OCP constraint that bans NC<sub>1</sub>VNC<sub>2</sub>. Furthermore, even if it were possible to engineer an OCP constraint that could penalize both NC<sub>1</sub>VNC<sub>2</sub> and NC<sub>1</sub>VN<sub>2</sub>V, without further amendment this constraint would not make predictions about directionality: it would also penalize N<sub>1</sub>VNC<sub>2</sub>. This is not the empirical result we want. While restrictions on NC<sub>1</sub>VN<sub>2</sub>V are widely discussed in the literature, restrictions on N<sub>1</sub>VNC<sub>2</sub> are not.<sup>14</sup> This directional asymmetry is, however, predicted by a contrast-based account. In N<sub>1</sub>VNC<sub>2</sub>V, all else being equal, NC<sub>2</sub> will be preceded by a nasalized vowel and followed by an oral vowel, rendering it maximally distinct from N and C. In other words, the problem that exists for NC<sub>1</sub>VN<sub>2</sub>V – that anticipatory nasalization from N<sub>2</sub> compromises the cues to N–NC<sub>1</sub> – does not exist for N<sub>1</sub>VNC<sub>2</sub>V.

There is, in addition, the fact that nasal cluster effects do not fit comfortably within the typology of dissimilation more generally. Dissimilatory processes tend to target segments that share one or more features (e.g. [+labial] or [+spread glottis]). As discussed in Chapter 2, NCs can, but are not necessarily, treated as single segments by the language's phonology (e.g. Riehl 2008); in Gurindji, for example, many of the NCs involved in nasal cluster effects are heterorganic and therefore likely clusters (McConvell 1988:142–143, McConvell 1993:20–24). Regardless of the segment vs. cluster status of an NC, however, they can only be characterized using a sequence of features (e.g. Steriade 1993a; see Anderson 1976 on difficulties of representing NCs with one feature matrix). And in Bennett's (2015) comprehensive survey of long-distance dissimilatory processes, the only processes listed that target sequences of features involve NCs (47).

(47) Summary of Bennett's (2015) survey<sup>15</sup>

<i>Segments</i>	<i>Featural description</i>	<i>No.</i>	<i>Language</i>
C Place	[+lab], [+cor], [+dors]	42	Akkadian
Nasal	[+nasal]	2	Takelma
Laryngeal Features	[+const. glottis], etc.	29	Chol
Continuancy	[+continuant]	5	Chaha
Liquids/Rhotics	[+cons], [+son], [±lat]	22	Latin
Sibilants	[+strident]	4	Nkore-Kiga
Voicing	[-voice]	29	Kinyarwanda
NC sequences	[+nasal][-nasal]	21	Gurindji

Why should NCs be the only exception to the generalization that dissimilatory processes target segments? Even if there were an obvious answer, the asymmetries discussed above would remain unexplained. An analysis under which nasal cluster effects are due to the activity of an OCP constraint, \*NC...NC, would thus fail to account for the observed facts and would require us to make the otherwise unmotivated claim that dissimilatory processes can target sequences of features. Given these shortcomings, it seems prudent to not adopt this approach.

<sup>14</sup>In Ngbaka (Ubangian, Thomas 1963), combinations of Ns and NCs are penalized regardless of order. Crucially, though, this doesn't appear to be motivated by an OCP constraint, as a single word can contain either multiple Ns or NCs (e.g. nzénzē, 'mouche à miel [honeybee]', Thomas p. 46). As identity-avoidance effects generally hold more strongly among elements that are more similar (see Suzuki 1998:17–19 for a review), it would be unusual for a language to ban combinations of Ns and NCs without also banning combinations of Ns or combinations of NCs.

<sup>15</sup>References are in Bennett's (2015) dissimilation database, downloadable from <http://www.cambridge.org/bennett>.

## 4.4 Locality

Another area where the contrast-based account makes testable predictions regards the locality of nasal cluster effects. The analysis developed above claims that these effects are local: when NC<sub>1</sub> is followed by an acoustically nasalized vowel, cues to the N–NC<sub>1</sub> contrast are compromised. So if something were to intervene between NC<sub>1</sub> and NC<sub>2</sub> to block the spread of nasality, we would not expect to find nasal cluster effects. The prediction here, then, is that if non-local nasal cluster effects exist, so should local nasal cluster effects – and the set of possible interveners should be limited to the set of segments that nasality can spread through. In almost all languages surveyed, this prediction is vacuously true: nasal cluster effects are only transvocalic.

The one clear exception to this generalization is Gurindji (Pama-Nyungan, McConvell 1988).<sup>16</sup> As with all other relevant languages, nasal cluster effects can apply locally ((48), repeated from (2)).

(48) NC<sub>2</sub> oralization in Gurindji (McConvell 1988:138)

- a. /kaŋju+mpal/ → [kaŋju+pal] ‘across below’  
(cf. [kajira-mpal] ‘across the north’)
- b. /kanka+mpa/ → [kanka-pa] ‘upstream’  
(cf. [kani-mpa] ‘downstream’)

What sets Gurindji apart from all other cases is that nasal cluster effects can also apply apparently non-locally, but the application of nasal cluster effects depends on the featural identity of the material intervening between the two NCs. As shown in Table 4.2, non-local application of NC<sub>2</sub> oralization can occur across all continuant consonants. Note that the data provided below simplify the Gurindji facts in non-crucial ways. For example, the only forms provided below are forms in which NC<sub>2</sub> is homorganic. The repair to NC<sub>1</sub>VNC<sub>2</sub>, however, differs according to whether NC<sub>2</sub> is homorganic or heterorganic. If NC<sub>2</sub> is homorganic, then N<sub>2</sub> deletes (NC → C). If however NC<sub>2</sub> is heterorganic, then N<sub>2</sub> loses its [+nasal] feature (NC → CC). I ignore this and other complications here; see McConvell (1988), Stanton (2016c) for further discussion.

Table 4.2: Examples of possible interveners in Gurindji NC<sub>2</sub> oralization

<i>Intervener</i>	<i>Form</i> <i>Gloss</i>	<i>Page</i>
...l...	/kankula- <u>mpa</u> / → [kankula- <u>pa</u> ] top-LOC (‘on the high ground’)	140
...ɬ...	/jawura-ŋ-ka <u>ŋ</u> i-kun <u>ŋ</u> ja/ → [jawura-ŋ-ka <u>ŋ</u> i-wu <u>ŋ</u> ja] steal-NOM-OTHER-COMIT (‘with another thief’)	140
...w...	/yaŋki-kumpalɨ/ → [yaŋki-wupalɨ] ride-LEST (‘to avoid riding’)	139
...j...	/ɲampa-wu-pa[a- <u>ji</u> -nta]/ → [ɲampa-wu-wa[a- <u>ji</u> -ta] what-DAT-NOW-1.SINGOBJ-2PLSUBJ	140

As shown in Table 4.3, however, if the intervening material contains a [-continuant] segment (e.g. a nasal consonant or an oral stop), then NC<sub>2</sub> modification is blocked. Beyond this constraint

<sup>16</sup>Depending on the analysis of Yindjibarndi (see section 4.3.4), it could also be a language in which nasal cluster effects apply non-locally. Since it is not clear that the analysis implicating non-local application is the correct one, however, I will not discuss that case further here. Esser & Mead (2011:19) also imply that nasal cluster effects can apply non-locally in Mori Bawah, but provide only one form, with no discussion of constraints on possible interveners.

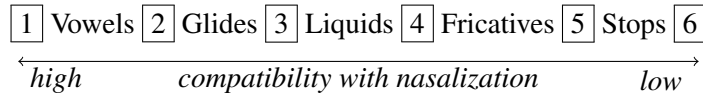
on intervening material, NC<sub>2</sub> oralization is unbounded (see McConvell 1988:144).

Table 4.3: Examples of blockers in Gurindji NC<sub>2</sub> oralization

<i>Blocker</i>	<i>Form</i> <i>Gloss</i>	<i>Page</i>
... <b>p</b> ...	[ŋu-ŋantipa-ŋkulu ja-ja] AUX-1.EXPLOBJ-3.PLSUBJ see-PAST	141
... <b>t</b> ...	[nampijita-wuŋja] female-LACKING	141
... <b>k</b> ...	[waŋji-ka-nta] which-LOC-2PS	141
... <b>m</b> ...	[kuja-ŋka-ma-ŋku pa-ni] thus-LOC-TOP-2SO hit-PAST	141
... <b>n</b> ...	[ŋu-n-juŋu-ŋku[a juwa-ni] AUX-2SS-RFL-LOC put-PAST	141

McConvell does not address the phonetics of nasality in Gurindji, but the set of possible interveners in NC<sub>2</sub> oralization bears a resemblance to known generalizations regarding the typology of nasal spreading (e.g. Schourup 1973, Walker 2000). These generalizations are illustrated in (49), where the ability of of nasality in a given language to spread through a segment type with some value  $x$  implies its ability to spread through all segment classes with values lower than  $x$ .

(49) Implicational hierarchy in nasal spreading (adapted from Walker 2000:26)



Given this, one interpretation of the facts in Tables 4.2 and 4.3 is that nasality spreads through segment types with a value of 4 or lower (i.e. liquids, glides, and vowels) in Gurindji. (The fact that intervocalic nasals do not participate in nasal harmony is typologically unusual, but not unprecedented – in Mehináku, described by Corbera Mori 2008, nasal stops also block the propagation of [+nasal].) But in the NC<sub>1</sub>...NC<sub>2</sub> context, the spread of nasality from NC<sub>2</sub> is prevented through deletion of N<sub>2</sub>, in order to avoid compromising the cues to the N–NC<sub>1</sub> contrast. Under this interpretation, nasal cluster effects in Gurindji are, as in all other known cases, exclusively local. (This analysis, when fleshed out more fully, amounts to a claim that NC<sub>2</sub> oralization in Gurindji is an example of *trigger deletion*, a type of non-myopic harmony pattern that has been argued to be unattested; on the debate regarding non-myopia see e.g. Wilson 2003, McCarthy 2009:12, Walker 2014. For a fuller elaboration of this analysis and its predictions, see Stanton 2016c.)

The Gurindji pattern, furthermore, poses a problem for theories of nasal cluster effects in which repairs like NC<sub>2</sub> oralization are driven by an OCP constraint, \*NC...NC. The sensitivity that Gurindji exhibits to the identity of the material between the two NCs does not resemble what we know about the typology of blocking in dissimilation. While it is common for dissimilatory processes to fail to apply (or to apply less regularly) as the offending segments grow further apart (e.g. Suzuki 1998, Zymet 2014), it is not clear that any attested dissimilatory pattern is sensitive to the identity of the intervening material. Every clear case of blocking in dissimilation (i.e. those cases discussed in Bennett 2015's Chapter 8) can be analyzed as an interaction among competing

co-occurrence constraints (Stanton 2016a; cf Suzuki 1998; Bennett 2015); the Gurindji pattern, however, lacks such an analysis. Dissimilatory processes tend to care about *how much* but not *what* material intervenes between the trigger and target segments, but N<sub>2</sub> modification in Gurindji displays the polar opposite preference.

## 4.5 Local summary

So far, we have seen that if we treat nasal cluster effects as perceptually-motivated contrast neutralization, many superficially dissimilar facts about the typology fall out. The contrast-based analysis correctly predicts a number of typological generalizations, ranging from conditions on possible repairs, to asymmetries in the types of sequences repaired, to restrictions on the locality of repairs. The true strength of the contrast-based approach is that it provides a unified account of these seemingly unrelated generalizations, based on a small set of well-established phonetic facts. The take-home point of this chapter so far, then, is that nasal cluster effects occur in response to a constraint that penalizes insufficiently distinct contrasts. No single existing alternative is capable of accounting for all of the generalizations that the contrast-based analysis can predict.<sup>17</sup>

There is thus good reason to believe that the cross-linguistic dispreference for NC<sub>1</sub>VNC<sub>2</sub> is due to the fact that nasalization of the intervening vowel, while necessary for C–NC<sub>2</sub> to remain sufficiently distinct, reduces cues to N–NC<sub>1</sub>. Put differently, what appears to be a dispreference for NC<sub>1</sub>VNC<sub>2</sub> is not a dispreference for the presence of multiple NCs within a single word *per se*, but rather a dispreference for NC $\tilde{V}$ . The rest of this chapter provides further support for this conclusion.

## 4.6 Predicted links between the NC $\tilde{V}$ and NC<sub>1</sub>VNC<sub>2</sub> typologies

While anticipatory nasalization of the intermediate vowel in NC<sub>1</sub>VNC<sub>2</sub> is one of the ways that NC $\tilde{V}$  sequences can arise, it is not the only way. Many languages also license contrasts in vocalic nasality: in languages with both phonemically nasal vowels and phonemic NC sequences, it is in principle possible for NC $\tilde{V}$  sequences, where  $\tilde{V}$  represents a phonemically nasal vowel, to occur. Naïvely, we would thus expect that languages in which maintaining maximally distinct N–NC<sub>1</sub> is a top priority should disprefer both NC $\tilde{V}$  and NC<sub>1</sub>VNC<sub>2</sub>.

There are, however, differences in the amount of nasalization exhibited by phonemically nasal and allophonically nasal vowels. In the cases I am aware of, phonemically nasal vowels are more nasalized than are allophonically nasalized vowels, both in the extent and intensity of acoustic nasality (see Cohn 1990 on French, de Medeiros 2011 on Brazilian Portuguese). Thus we might expect that N–NC<sub>1</sub> will be more distinct in NC<sub>1</sub>VNC<sub>2</sub>, where the intervening vowel is less nasalized, than in NC $\tilde{V}$ , where the following vowel is more nasalized. In other words, we expect  $\Delta$  N–NC is greater in NC<sub>1</sub>VNC<sub>2</sub> than it is in NC $\tilde{V}$ . Assuming this is true, the predictions in (50) should hold.

- (50) Predictions regarding NC $\tilde{V}$  and NC<sub>1</sub>VNC<sub>2</sub> licensing
- a. If a language allows NC $\tilde{V}$ , it should also allow NC<sub>1</sub>VN<sub>2</sub>(C).
  - b. If a language bans NC<sub>1</sub>VN<sub>2</sub>(C), it should also ban NC $\tilde{V}$ .

<sup>17</sup>One might wonder at this point about the appropriateness of a diachronically-motivated analysis, in which sound changes occur due to innocent misapprehension of indistinct contrasts over time (e.g. Blevins 2004; see Chapters 2 and 3 for additional discussion). The existence of repairs like NC<sub>2</sub> oralization (NC<sub>1</sub>VNC<sub>2</sub> → NC<sub>1</sub>VC<sub>2</sub>) make it difficult to formulate such an account, though, as NC<sub>2</sub> oralization effectively *removes the problem* of an indistinct N–NC<sub>1</sub> contrast. Thus NC<sub>2</sub> oralization is in some ways a form of enhancement – it renders N–NC<sub>1</sub> more distinct.

The predictions in (50) follow straightforwardly from 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  $C_2$  (where it is less well-cued) implies its presence in  $C_1$  (where it is better-cued). Relatedly, if  $x-y$  is banned from appearing in  $C_1$  (where it is better-cued), then all else being equal,  $x-y$  should be banned in  $C_2$  (where it is less well-cued). So given that  $\Delta N-NC / \_VNC > \Delta N-NC / \_V$ , we expect (50a–b) to hold. In what follows, I show that they do.

#### 4.6.1 Prediction #1: $NC\tilde{V}$ implies $NC_1VNC_2$

To test the prediction that the existence of  $NC\tilde{V}$  in a given language should imply the existence of  $NC_1VN_2(C)$ , I conducted a survey to find languages that might allow  $NC\tilde{V}$ , i.e. those that allow both NCs as well as a contrast in vocalic nasality. This survey was drawn from a large collection of reference grammars at MIT's Hayden Library, as well as assorted online periodicals (e.g. UCLA's Working Papers in Phonetics). An important criterion for inclusion in this survey was that NCs have phonemic status (i.e. they contrast with Cs and Ns): this means that languages such as Apinayé and Siriono, although identified by Maddieson (1984) as allowing both NCs and  $V-\tilde{V}$ , do not qualify. In Apinayé and Siriono, as well as many other South American languages, Ns and NCs are allophonic variants conditioned by the quality of the neighboring vowels (see Chapter 3 on environmental shielding). As the focus here is on the effects of vocalic nasality on the N–NC contrast, these languages are not directly relevant for the discussion that follows.

Altogether, 23 languages licensing both N–NC and  $V-\tilde{V}$  were identified in the survey; see section 4.7 for a full list of the languages included in the survey, as well as their sources. Of these 23 languages, 12 allow  $NC\tilde{V}$  sequences (the analysis of languages that allow  $NC\tilde{V}$ , versus those that do not, will be developed in section 4.7). As predicted, all languages that allow  $NC\tilde{V}$  also allow  $NC_1VN_2(C)$ .<sup>18</sup> These results are provided in Table 4.4, below (where applicable, gloss translations are mine). For each language, I provide forms supporting the claim that a  $V-\tilde{V}$  contrast is licensed following NCs, as well as forms supporting the claim that these languages also allow  $NC_1VN_2(C)$ . Recall from Chapter 2 that the two systems in which  $NC_1VNC_2$  forms are not reported, Lua and Mbum, are also systems that only allow NCs in initial position: NCs cannot follow any other consonant, regardless of its identity. In other words, there are independent reasons why  $NC_1VN_2$  forms are licit in these languages, but  $NC_1VNC_2$  forms are not.

#### 4.6.2 Prediction #2: $*NC_1VNC_2$ implies $*NC\tilde{V}$

To test the prediction that a language banning  $NC_1VN_2(C)$  must also ban  $NC\tilde{V}$ , I attempted to find adequate information about the vocalic inventories of each language included in the survey of nasal cluster effects. Of the 67 languages surveyed, I was able to find this information for 49 (sources provided in the appendix). Of these 49, only two – Saramaccan (McWhorter & Good 2012) and Sango (Samarin 1967) – license a contrast in vocalic nasality. As predicted, neither allows  $NC\tilde{V}$ .

##### Saramaccan

Although there are no alternations in Saramaccan to show us that underlying  $NC_1VNC_2$  sequences are modified in some way, McWhorter & Good (2012:26) note that “multiple prenasalized stops in

<sup>18</sup>Note also that each of the systems in Table that allows  $NC\tilde{V}$  sequences also allows  $NCV$  sequences. This may seem unexceptional, but it is predicted by a contrast-based account: if NC is permitted to surface before a nasal vowel (where it is presumably less distinct from a nasal consonant; see Beddor & Onsuwan 2003), it must also be able to surface before an oral vowel (where it is more distinct from a nasal consonant).



Table 4.4: Languages that allow NC $\tilde{V}$  also allow NC<sub>1</sub> VN<sub>2</sub>(C)

Language (Source)	NCV–NC $\tilde{V}$	NC <sub>1</sub> VNC <sub>2</sub>
Day (Nougayrol 1979)	ndéé ‘people’ (p. 61) ndé ‘little’ (p. 61)	mbòmbórò ‘jawbone’ (p. 35) ndèèm ‘to suffice’ (p. 61)
Kabba (Moser 2004)	mbī ‘ear’ (p. 36) mbī ‘nausea’ (p. 36)	ngèm ‘lie’ (p. 20) mbámbá ‘soldier’ (p. 20)
Lua (Boyeldieu 1985)	mbàrì ‘to flatten’ (p. 43) mbá: ‘regularly’ (p. 43)	ndōŋ ‘it’s too wide, narrow’ (p. 49) ndwààm ‘Ndam of Ndam’ (p. 52)
Mbay (Keegan 1996)	mbòj ‘in a panic’ (p. 293) mbòj ‘pleasantly’ (p. 294)	ngōn ‘son, daughter’ (p. 355) mbíndíng ‘very heavy’ (p. 290)
Mbum (Hagège 1970)	nzáu ‘spark’ (p. 41) nzá ‘balafon’ (p. 59)	mbàm ‘rain’ (p. 30) ndàm ‘poison’ (p. 32)
Ngambay (Vandame 1963)	ndà ‘to be white’ (p. 197) ndà ‘to pick’ (p. 15)	ndàng ‘to be crazy’ (p. 9) mbūnā ‘interval’ (p. 197)
Ngbaka (Thomas 1963)	zàlānzè ‘orange’ (p. 46) nzē ‘blood’ (p. 30)	mbàngà ‘river sand’ (p. 28) mbānā ‘wing’ (p. 50)
Nizaa (Endresen 1991)	mbēē ‘to judge’ (p. 42) mbēē ‘to limp’ (p. 42)	mbèmbèm ‘wind instrument’ (p. 48) ndaŋnì ‘disobedience’ (p. 48)
Tinrin (Osumi 1995)	ŋdī ‘leaf, be humid’ (p. 17) ŋdū ‘hawk’ (p. 15)	ŋdaŋdōŋ ‘to hurt the foot...’ (p. 5) ŋdīnawa ‘coconut leaves’ (p. 290)
Vouté (Guarisma 1978)	ngór ‘thinness’ (p. 45) ngóō ‘grass sp.’ (p. 45)	ngúŋ ‘stick’ (p. 45) ngónbé ‘paddle’ (p. 24)
Xârâcùù (Lynch 2002b)	baru ‘two’ (p. 768) mb <sup>w</sup> ā ‘distant and invisible’ (p. 768)	ndomb <sup>w</sup> a ‘thing’ (p. 775) mbanī: ‘how many?’ (p. 775)
Yakoma (Boyeldieu 1975)	pëndá ‘back’ (p. 126) ndé ‘different(ly)’ (p. 100)	ngúni ‘the water falls...’ (p. 22) ngàmbíi ‘youngest’ (p. 39)

direct succession in a single morpheme are quite rare,” with only one existing example (*bingúngu* ‘stink bug’). More generally, they note that “the occurrence of multiple prenasalized stops [...] anywhere with a single morpheme is rare,” and that there is only one known example (*mfáfumbá* ‘animal type’). Clearly, then, there is a marked dispreference for NC<sub>1</sub> VNC<sub>2</sub> sequences, and perhaps NC<sub>1</sub>...NC<sub>2</sub> more generally (though more data is necessary to verify this).

Unlike most languages that exhibit a dispreference for NC<sub>1</sub> VNC<sub>2</sub> sequences, Saramaccan also licenses a contrast in vocalic nasality, as demonstrated by the examples in (51).

(51) Vocalic nasality contrast in Saramaccan (McWhorter & Good 2012:19)

- a. pétí ‘puddle’ vs. pětí ‘comb’
- b. hási ‘horse’ vs. hásí ‘ant’

Nasal vowels are, however, generally disallowed following NCs. McWhorter & Good (2012:26) note explicitly that words containing NC $\tilde{V}$  sequences are rare; the only attested example of a word containing NC $\tilde{V}$  is the ideophone *gíngí/gíngí* ‘stuck fast’, and even in this case there is variation between NCV and NC $\tilde{V}$ . Thus in Saramaccan, a ban on NC<sub>1</sub> VNC<sub>2</sub> goes hand-in-hand with a ban on NC $\tilde{V}$ . This is exactly what the contrast-based analysis predicts.

## Sango

While the ban on NC<sub>1</sub>VNC<sub>2</sub> and NC $\tilde{V}$  in Saramaccan appears to be meaningful, it is less clear that this is the case for Sango. While Meeussen (1963) lists Sango as a language that exhibits NC<sub>1</sub> nasalization (albeit to a limited degree), there is no mention of NC<sub>1</sub> nasalization in Samarin's (1967) description – while there is minor allophonic variation between NCs, Ns, and Cs, it does not appear to be conditioned by anything (Samarin 1967:46) – and morphemes containing multiple NCs, or sequences of NCs followed by Ns, are not difficult to find (52).

- (52) NC<sub>1</sub>VN<sub>2</sub>(C) forms in Sango (Samarin 1967:35–36)
- a. ngunzá 'manioc leaves'
  - b. ndóndó 'brain'
  - c. mbéní 'some'

As it is unclear what the discrepancy between Meeussen's (1963) and Samarin's (1967) descriptions is due to, I thought it prudent to continue the investigation into Sango's vocalic inventory, where there is a contrast between oral and nasal vowels (53).

- (53) Vocalic nasality contrast in Sango (Samarin 1967:38)
- a. fú 'to sew' vs. f $\acute{u}$  'to smell'
  - b. kɛ 'to be' vs. k $\acute{e}$  'to refuse'

Samarin does not explicitly discuss any restrictions on the distribution of nasal vowels, mentioning only that they are “very few in number and minimally contrastive” (p. 47). A search through Chapters 1–9 of the grammar (pp. 31–162), as well as the lexicon (pp. 259–267), does not reveal any NC $\tilde{V}$  sequences. Thus in Sango there appears to be a ban on NC $\tilde{V}$  sequences, but it is unclear at present what the status of NC<sub>1</sub>VN<sub>2</sub>(C) is, and if by extension there is any meaningful result here.

### 4.6.3 Comparison with alternatives

This section has validated two further predictions of the contrast-based approach to nasal cluster effects: that languages banning NC<sub>1</sub>VNC<sub>2</sub> should also ban NC $\tilde{V}$  (50a), and that languages allowing NC $\tilde{V}$  should also allow NC<sub>1</sub>VNC<sub>2</sub> (50b).

Before moving on, it is important to note that these predictions would not be expected to hold under a theory in which nasal cluster effects are dissimilatory processes, motivated by an OCP constraint. Such a theory would not predict any sort of link between the NC<sub>1</sub>VNC<sub>2</sub> and NC $\tilde{V}$  typologies, as the OCP constraint penalizing NC<sub>1</sub>VNC<sub>2</sub> would not apply to NC $\tilde{V}$ . We would thus expect to find languages that allow NC $\tilde{V}$ , but ban NC<sub>1</sub>VNC<sub>2</sub>, due to high-ranked \*NC...NC. The absence of such systems suggests that there is no constraint penalizing NC<sub>1</sub>VNC<sub>2</sub> to the exclusion of NC $\tilde{V}$ . Put differently, the observed link between the NC $\tilde{V}$  and the NC<sub>1</sub>VNC<sub>2</sub> typologies suggests that the desire to avoid indistinct N–NC contrasts is not just one possible source of nasal cluster effects, but that it is the *only* source of nasal cluster effects.

## 4.7 Analysis and extensions

In the last part of this chapter, we return to the survey discussed introduced in section 4.6, which focuses on languages that license both an N–NC contrast and a contrast in vocalic nasality. The full results of the survey are presented in Table 4.5: 12 languages permit NC $\tilde{V}$  sequences, while 11 ban them. In some of these 11 descriptions (e.g. Gbeya, Samarin 1966; Saramaccan, McWhorter &

Table 4.5: NC $\tilde{V}$  survey results

Allows NC $\tilde{V}$ <i>12 lgs.</i>	Bans NC $\tilde{V}$ <i>11 lgs.</i>
Day (Nougayrol 1979)	Acehnese (Durie 1985)
Kabba (Moser 2004)	Apinayé (Oliveira 2005)
Lua (Boyeldieu 1985)	Gbaya Kara (Monino & Roulon 1972)
Mbay (Keegan 1996, 1997)	Gbeya (Samarin 1966)
Mbum (Hagège 1970)	Ndumbea (Gordon & Maddieson 1999)
Ngambay (Vandame 1963)	Nheengatu (Moore et al. 1993)
Ngbaka (Thomas 1963; Henrix et al. 2015)	Páez (Rojas Curieux 1998; Jung 2008)
Nizaa (Endresen 1991)	Paici (Gordon & Maddieson 2004)
Tinrin (Osumi 1995)	Sango (Samarin 1967)
Vouté (Guarisma 1978)	Saramaccan (McWhorter & Good 2012)
Xârâcùù (Lynch 2002b)	Vai (Welmers 1976)
Yakoma (Boyeldieu 1975)	

Good 2012), the author is explicit about the restriction on NC $\tilde{V}$ ; for others, the author is silent, and the restriction is inferred through the absence of such forms in the description (e.g. Sango, Samarin 1967; Gbaya Kara, Monino & Roulon 1972).

#### 4.7.1 Analysis

We have already part of the explanation for why NC $\tilde{V}$  sequences are dispreferred: the presence of a nasal vowel following NC renders it confusable with a plain nasal. But in systems that also license a contrast in vocalic nasality, another factor comes into play: namely, that in NC $\tilde{V}$  contexts, constraints on the V– $\tilde{V}$  and N–NC contrasts conflict. While rendering NC maximally distinct from N in an NC $\tilde{V}$  sequence would require oralizing at least part of the nasal vowel, enhancing the cues to N–NC in this way would reduce cues to V– $\tilde{V}$ , as we expect that oralizing the initial portion of a nasal vowel should render it less distinct from an oral vowel. In other words, the distinctiveness requirements of the N–NC and V– $\tilde{V}$  contrasts are mutually antagonistic; in NC $\tilde{V}$  contexts, they come into direct conflict. This state of affairs is schematized in (54). While increasing the amount of oralization in the following nasal vowel from 25 units to 50 units enhances the cues to the N–NC contrast ((54a) vs. (54c)), it does so at the expense of reducing cues to the V– $\tilde{V}$  contrast ((54a) vs. (54b)). (The schematic illustrations below include NC $\tilde{V}$ , NCV, N $\tilde{V}$ , but not NV; this simplification was made for expository purposes.)

(54) Enhancing cues to N–NC reduces cues to V– $\tilde{V}$

a.	NC	<table><tr><td>V<sub>25</sub></td><td>→</td><td><math>\tilde{V}_{50}</math></td></tr></table>	V <sub>25</sub>	→	$\tilde{V}_{50}$
V <sub>25</sub>	→	$\tilde{V}_{50}$			
b.	NC	<table><tr><td>V</td></tr></table>	V		
V					
c.	N	<table><tr><td><math>\tilde{V}</math></td></tr></table>	$\tilde{V}$		
$\tilde{V}$					

This conflict between distinctiveness constraints can be formalized as in (55). Let us assume that, in some language, undominated  $\Delta$  FQUALITY (S<sub>2</sub>-50) requires Ns to be followed by a vowel that is at least 50 units nasal, and NC by a vowel that is 50 units oral. Let us also assume that this

language licenses a contrast in vocalic nasality, and that another undominated MINDIST constraint, NASDUR<sub>≥75</sub>, requires a nasal vowel to be at least 75 units nasal to be sufficiently distinct from an oral vowel (see Chapter 3 for discussion of NASDUR constraints). In this situation, simultaneous satisfaction of both Δ FQUALITY (S<sub>2</sub>-50) and NASDUR<sub>≥75</sub> is impossible.<sup>19</sup> Candidate (55a), the faithful candidate, is eliminated by a violation of Δ FQUALITY (S<sub>2</sub>-50), as the vowel following NC is only 25 units oral; candidate (54b), where the amount of oral coarticulation has been increased to satisfy Δ FQUALITY (S<sub>2</sub>-50), incurs a fatal violation of NASDUR<sub>≥75</sub>, because the nasal vowel is only 50 units nasal. The two remaining candidates satisfy both distinctiveness constraints, but incur various other faithfulness violations: in (55c), the V- $\tilde{V}$  contrast is neutralized post-NC; in (55d), the N-NC contrast is neutralized pre- $\tilde{V}$ . Whichever contrast is neutralized, the result is a ban on NC $\tilde{V}$ . (For the nine systems that ban NC $\tilde{V}$ , it is impossible to know which of the N-NC and V- $\tilde{V}$  contrasts is neutralized, as there is no evidence from alternations: there is only a static ban on NC $\tilde{V}$ .)

(55) Ban on NC $\tilde{V}$  sequences is a ban on indistinct contrasts

	NC <sup>V25</sup> $\tilde{V}_{75}$ NCV N $\tilde{V}$	Δ FQUALITY (S <sub>2</sub> -50)	NASDUR <sub>≥75</sub>	FAITH
a.	NC <sup>V25</sup> $\tilde{V}_{75}$ NCV N $\tilde{V}$	*!		
b.	NC <sup>V50</sup> $\tilde{V}_{50}$ NCV N $\tilde{V}$		*!	
c.	NCV NCV N $\tilde{V}$			*
d.	N $\tilde{V}$ NCV N $\tilde{V}$			*

There are a couple of possibilities as to what the difference is between those systems that license NC $\tilde{V}$  (e.g. Ngambay, Vandame 1963) and those that don't (e.g. Acehnese, Durie 1985). The difference between these two classes of systems could be localized to the relative ranking of distinctiveness constraints and faithfulness constraints: if neutralizing either N-NC or V- $\tilde{V}$  is not an option, then the language would be forced to license an insufficiently distinct contrast. The difference could also be localized to the relative strictness of the distinctiveness constraints that regulate the N-NC and V- $\tilde{V}$  contrasts: for example, perhaps the languages that ban NC $\tilde{V}$  require NC to be followed by a vowel that is 50 units oral, but in the languages that license NC $\tilde{V}$ , NC can be followed by a vowel that is less oral (say 25 units) and still be distinct from N. Under this latter scenario, the difference between the two classes of systems lies in the amount of time required for the cues to N-NC and V- $\tilde{V}$  to be sufficiently realized. Deciding which of these analyses is correct, however, would require in-depth study of the surveyed languages, and I do not speculate further here.

#### 4.7.2 The role of vowel length

The analysis above assumes that all vowels have the same total duration, but now let's consider what might happen in a language that has both long and short vowels. Let us assume that in the schematic language in (56–57), long vowels are twice as long as short vowels – and that, regardless of the length of the nasal vowel in NC $\tilde{V}$  sequences, NC induces the same temporal extent of coarticulatory oralization. The result is that the nasal vowel in NC $\tilde{V}$  sequences is proportionally more nasal when the vowel is long ((57a), where both distinctiveness constraints can be satisfied) than it is when the vowel is short ((56), where there is not enough time for both distinctiveness constraints to be satisfied).

<sup>19</sup>It is impossible to render N-NC and V- $\tilde{V}$  sufficiently distinct only if we assume that the vowel is incapable of lengthening to satisfy NASDUR<sub>≥75</sub>. Such a restriction could be formalized with the addition of a faithfulness constraint that penalizes vowel lengthening from the Realized Input to the output.

(56) Short vowels:  $\Delta$  FQUALITY ( $S_2$ -50) and NASDUR<sub>75</sub> cannot both be satisfied.

- a. NC 

V <sub>50</sub>	$\tilde{V}_{50}$
-----------------	------------------
- b. NC 

V <sub>100</sub>
------------------
- c. N 

$\tilde{V}_{100}$
-------------------

(57) Long vowels:  $\Delta$  FQUALITY ( $S_2$ -50) and NASDUR<sub>≥75</sub> can both be satisfied..

- a. NC 

V <sub>100</sub>	$\tilde{V}_{100}$
------------------	-------------------
- b. NC 

V <sub>200</sub>
------------------
- c. N 

$\tilde{V}_{200}$
-------------------

The contrast-based account predicts that there should be three types of systems: (i) those that ban all instantiations of NC $\tilde{V}$ , (ii) those that permit all instantiations of NC $\tilde{V}$ , and (iii) those that permit NC $\tilde{V}$ : (where the vowel is long), but ban NC $\tilde{V}$  (where it is short). This is because it is possible to formulate a MINDIST constraint that can penalize (56) (e.g. NASDUR<sub>≥75</sub>), as well as a MINDIST constraint that can penalize both (56) and (57) (e.g. NASDUR<sub>≥125</sub>), but it is impossible to formulate a MINDIST constraint that could penalize (57) to the exclusion of (56).

The implicational generalization predicted, then, is that if a language allows NC $\tilde{V}$  (where the vowel is short), it should also allow NC $\tilde{V}$ : (where the vowel is long). For all languages surveyed, this prediction holds. Furthermore, below I provide some evidence that at least one language included in the survey (Mbay, Keegan 1996, 1997), and potentially two or three (Lua, Boyeldieu 1985; Mbum, Hagège 1970) display the predicted asymmetry: NC $\tilde{V}$  sequences are preferred when  $\tilde{V}$  is long, and dispreferred when  $\tilde{V}$  is short.

## Methodology

To test the prediction that NC $\tilde{V}$  (where the vowel is short) should be dispreferred to NC $\tilde{V}$ : (where the vowel is long), I fit loglinear models (described below) to counts from six corpora. The corpora were either lexica or dictionaries, and I used one for each of six languages (Nougayrol 1979 for Day; Boyeldieu 1985 for Lua; Keegan 1996 for Mbay; Vandame 1974 for Ngambay; Henrix et al. 2015 for Ngbaka; and Guarisma 1978 for Vouté). These six corpora constitute the entire body of available evidence, as these six are the only NC $\tilde{V}$ -allowing languages that have associated corpora available to me.<sup>20</sup>

The findings of the study, in short, are that while not all languages exhibit a preference for NC $\tilde{V}$ : over NC $\tilde{V}$  (and more generally, NCV over NC $\tilde{V}$ ), there is no language that exhibits the opposite preference. The following subsections discuss in detail the two languages whose corpora suggest a preference for NC $\tilde{V}$ : over NC $\tilde{V}$ , and in less detail some aspects of the results for the remaining four languages whose corpora did not display such a preference. For summaries of all results, see Appendix B (section 4.10).

<sup>20</sup>There is, in addition, a dictionary available for Kabba (Moser & Dingatoloum 2007). The dictionary does not however distinguish nasal vowels and vowel-nasal sequences orthographically (both are written as VN), so it was not informative for the present purposes.

## Mbay

In Mbay (Nilo-Saharan; Keegan 1996, 1997), vowels contrast for length, albeit to a limited extent. While minimal pairs are attested (examples in (58)), the distribution of vowel length is for the most part predictable.

(58) Vowel length contrast in Mbay (Keegan 1996:7)

- |    |             |     |                  |
|----|-------------|-----|------------------|
| a. | tò ‘lie’    | vs. | tòò ‘pirogue’    |
| b. | ndī ‘voice’ | vs. | ndīi ‘rain’      |
| c. | tō ‘carry’  | vs. | tōo ‘hurt, pain’ |

The vowels in disyllabic (and presumably longer) words are almost always short (e.g. *kídā* ‘scorn,’ Keegan 1997:14). In monosyllabic morphemes consisting of a single open syllable, the vowel is almost always long (e.g. *tòò* ‘pirogue’), though exceptions do exist – short vowels can be found in interrogative pronouns and some function words, as well as some formerly disyllabic words that have lost their initial vowels (e.g. *tō* ‘carry’, with a short vowel, corresponds to *ətō* in Sar and *itō* in Daba, both related languages; see Keegan 1997:8). In monosyllabic morphemes consisting of a single closed syllable, the vowel is almost always short (e.g. *ndār* ‘skin,’ Keegan 1997:10).

In addition to licensing a contrast in vowel length, Mbay also licenses a contrast in vocalic nasality, in both short and long vocalic contexts. Examples follow in (59).<sup>21</sup>

(59) Nasality contrasts in Mbay (Keegan 1996:5)

- |    |                 |     |                 |
|----|-----------------|-----|-----------------|
| a. | òo ‘forge’      | vs. | òõ ‘burn; eat’  |
| b. | kórā ‘one’      | vs. | kǎrá ‘accuse’   |
| c. | kār ‘clearness’ | vs. | kǎr ‘toad/frog’ |

Finally, in addition to these vocalic contrasts, Mbay also licenses contrasts between NCs, obstruent stops, and nasals. While NCs (along with plain obstruent stops) are banned from occurring in word-final position, they can occur word-initially or word-medially, in prevocalic position (60).

(60) Prevocalic NCs in Mbay

- |    |               |                            |                 |
|----|---------------|----------------------------|-----------------|
| a. | ngóo          | ‘skin, pod, peel’          | Keegan 1996:358 |
| b. | ndōw          | ‘crackle’                  | Keegan 1997:4   |
| c. | mbōlí         | ‘snake magician; magician’ | Keegan 1996:293 |
| d. | sùmbā ~ sèmbā | ‘to be on target’          | Keegan 1997:37  |

Given this, in Mbay we would expect to find the following eight kinds of consonant-vowel sequences: NCV (NC followed by short oral V), NCV: (NC followed by long oral V), NC $\tilde{V}$  (NC followed by short nasal V), NC $\tilde{V}$ : (NC followed by long nasal V), CV (non-NC followed by short oral V), CV: (non-NC followed by long oral V), C $\tilde{V}$  (non-NC followed by short nasal V), and C $\tilde{V}$ : (non-NC followed by long nasal V). An investigation of Keegan’s (1996) dictionary (containing 11,544 consonant-vowel sequences, from 5,558 words) reveals all eight consonant-vowel sequence types are attested – but as is clear from (61), some are more frequent than others.<sup>22</sup>

<sup>21</sup>Note that the transcriptions of Mbay forms provided in this chapter differ somewhat from the forms that Keegan provides. Keegan notes that “nasalization spreads to all vowels within a morpheme”, but transcribes only one vowel per morpheme as nasal. The transcriptions here mark all vowels in a nasal morpheme as nasal.

<sup>22</sup>The dictionary was transcribed into a text file by hand; a Python script was used to automate the counts.

(61) Frequencies of consonant-vowel sequences in Mbay (Keegan 1996)

<i>Form</i>	<i>Count</i>	<i>Form</i>	<i>Count</i>
CV	8185	NCV:	259
CV:	1300	C $\tilde{V}$	153
NCV	1243	NC $\tilde{V}$ :	52
C $\tilde{V}$ :	344	NC $\tilde{V}$	8

From (61) it appears that NC $\tilde{V}$ (:) sequences (with both a short and a long vowel) are generally rare, and that NC $\tilde{V}$  (with a short vowel) is even rarer. But before concluding anything from this, there are other factors that need to be controlled for. For example: NCs are rarer than Cs, and  $\tilde{V}$ (:)s are rarer than V(:)s; could the low incidence of NC $\tilde{V}$ (:) be due to the independent rarity of NCs and  $\tilde{V}$ (:)s? And could the low incidence of NC $\tilde{V}$  (as compared to NC $\tilde{V}$ (:)) simply be an side effect of the relative rarity of short  $\tilde{V}$ s as compared to long  $\tilde{V}$ :s?

I evaluated the question of whether or not Mbay exhibits a dispreference for NC $\tilde{V}$ (:) by fitting a loglinear model to the data in (61) (using the `glm` function of R's `lme4` package; Bates & Maechler 2011). The model was supplied with the count data in (61) and the factors that are relevant to that data, with the goal of determining which factors, or combinations of factors, are significant predictors of the count data. For the data in (61), the relevant factors are *consonant identity* (C vs. NC), *vowel quality* (V(:) vs.  $\tilde{V}$ (:)), and *vowel length* (V/ $\tilde{V}$  vs. V:/ $\tilde{V}$ :) (in the model, all factors were dummy-coded, and the unmarked values, i.e. non-NC, oral vowel, and short vowel, were treated as the baseline values). If it were the case that all possible combinations of these parameters were equally probable, we might expect the frequency of all kinds of forms to be roughly equivalent. But in (61) this isn't the case. So we have to ask: what is responsible for the skew?

As is evident from the results in Table 4.6, the count data result from a complex interplay among the factors included in the model: each factor and combination of factors (interactions indicated with an asterisk, \*) significantly affects the count data. I follow standard convention here and consider an effect significant if  $p \leq .05$  (roughly, if the Z-Statistic  $\geq |2|$ ), as assessed by the Wald test. In Table 4.6, a factor or interaction with a negative coefficient means that the structure listed occurs less frequently in the corpus; a factor or interaction with a positive coefficient means that the structure listed occurs more frequently.

The important points to take away from these results are as follows. Even when the independent rarity of both NCs and  $\tilde{V}$ s is controlled for (a–b in Table 4.6), the NC\* $\tilde{V}$  interaction (e) indicates that NC $\tilde{V}$  is dispreferred beyond what we would expect. Thus even in a language that allows NC $\tilde{V}$  sequences to surface, we find what appears to be a gradient dispreference (see the end of this section for more discussion on this point). In addition, even when the preferences for NCs to be followed by long vowels (d)<sup>23</sup> and for nasal vowels to be long (e) are controlled for, the three-way NC\*V(:)\* $\tilde{V}$  interaction in (g) indicates that NC $\tilde{V}$ (:) is preferred beyond what we'd expect; in other words, NC $\tilde{V}$  sequences are more frequent when the vowel is long. As predicted, then, Mbay exhibits an (albeit gradient) dispreference for NC $\tilde{V}$  (where the vowel is short).

It is important to note that the observed effects cannot all be attributed to a dispreference for CV sequences that contain multiple marked structures. Note, in particular, that the V:/\* $\tilde{V}$  interaction in (f) shows us that a combination of two marked things – long vowels (b) and nasal vowels (c) – is *more frequent* than we might otherwise expect.

<sup>23</sup>Why do NCs generally prefer to be followed by long vowels? One possibility is that a long vowel, regardless of its quality, allows more time for cues to the N–NC contrast to be realized: a long oral vowel, for example, provides the listener with more evidence that the preceding consonant was also oral.

Table 4.6: Results for Mbay poisson regression

Factor	Coefficient	Z-Statistic	Significant?	Interpretation
Intercept	9.01			
a. NC	-1.88	-61.92	Yes ( $p < .001$ )	NCs are less frequent than are other kinds of consonants.
b. V:	-1.84	-61.63	Yes ( $p < .001$ )	Long vowels are less frequent than short vowels.
c. $\tilde{V}$	-3.98	-48.77	Yes ( $p < .001$ )	Nasal vowels are less frequent than oral vowels.
d. NC*V:	0.27	3.64	Yes ( $p < .001$ )	NCs are more frequent when followed by long vowels, than they are when followed by short vowels.
e. NC* $\tilde{V}$	-1.07	-2.93	Yes ( $p < .01$ )	NCs are less frequent when followed by nasal vowels, than they are when followed by oral vowels.
f. V: * $\tilde{V}$	2.65	26.07	Yes ( $p < .001$ )	Nasal vowels are more frequent when they are long.
g. NC*V: * $\tilde{V}$	0.79	1.98	Yes ( $p < .05$ )	NC $\tilde{V}$ (:) sequences are more frequent when the nasal vowel is long.

Assuming that the reduced frequency of some structure  $S$  in a corpus constitutes evidence that  $S$  is dispreferred, evidence from the Mbay corpus corroborates the prediction that NC $\tilde{V}$  should be preferred when the vowel is long. Regarding the analysis of these effects, I assume that the gradient dispreference for NC $\tilde{V}$  in Mbay can be attributed to the same distinctiveness constraints that have been shown to predict parallel categorical effects in the discussion above. I leave the question of how to integrate constraints on contrast with probabilistic models of phonotactics (e.g. Maxent models; see e.g. Goldwater & Johnson 2003, Jäger 2007, Hayes & Wilson 2008) to future work.

## Lua

So far, we have seen evidence that Mbay (Keegan 1996, 1997) gradiently prefers NC $\tilde{V}$  in contexts where  $\tilde{V}$  is long to NC $\tilde{V}$  in contexts where  $\tilde{V}$  is short. But do we find a language that sets a cutoff? Do we find a language that allows NC $\tilde{V}$ :, for example, to the exclusion of  $\tilde{V}$ ?

Lua (Niger-Congo, Boyeldieu 1985), at first glance, appears to be that language. The distribution of consonantal and vocalic contrasts is more restricted in Lua than in the other languages considered thus far. Vowels contrast for length and nasality, but these contrasts are limited to initial syllables. Minimal or near-minimal pairs demonstrating contrasts in vowel length and nasality follow (62); all gloss translations from French are mine.

- (62) Vowel length and nasality contrasts in Lua (page numbers from Boyeldieu 1985)
- a. pāṛ ‘suivre [to follow]’ vs. pāṛr ‘raconter, dire [to say, to tell]’ p. 126
  - b. kār ‘varan [lizard sp.]’ vs. kār̃ ‘palmes du doum [doum palm]’ p. 118

As noted in Chapter 2, Lua also licenses contrasts among Ns, Cs, and NCs, though the distribution of NCs is limited to word-initial position. A couple of examples follow (63).



- (63) Word-initial NCs in Lua (Boyeldieu 1985:44)
- a. mbè:rí ‘innocence’
  - b. ndíl ‘name’

Given these restrictions on the distribution of nasal vowels and NCs, we would naïvely expect to find forms beginning with both NC $\tilde{V}$  and NC $\tilde{V}$ :. This is, however, not what we find. There are only four forms that begin with NC $\tilde{V}$ :, and in all of them, the nasal vowel is long. (In (64), the orthographic sequence *ya* represents a rising-sonority diphthong.)

- (64) Word-initial NC $\tilde{V}$ :. in Lua (all examples pp. 41–49, Boyeldieu 1985)
- a. mbyā: ‘deadfall trap’
  - b. mbā: ‘regularly’
  - c. ndyāā: ‘first stage of millet beer’
  - d. ndā: ‘hut wall’

A potential explanation for why Lua prefers to license NC $\tilde{V}$  sequences only in long monosyllables has two parts. First, we must explain why NC $\tilde{V}$  is restricted to contexts where  $\tilde{V}$  is phonemically long. This much is simple: as discussed above, NC $\tilde{V}$  sequences should be better-tolerated when the vowel is long. Second, we must explain why NC $\tilde{V}$  is restricted to long monosyllables: given that NC $\tilde{V}$ :rV is a possible word shape, for example, why are NC $\tilde{V}$  sequences not tolerated in this context? A possible answer comes from the hypothesis that vowels in monosyllabic words are often longer than vowels in longer words. While (to the best of my knowledge) a link between monosyllabicity and length has not been verified for Lua, there is some cross-linguistic support for its existence. It has been shown for a limited number of languages that syllables in shorter words are generally longer than syllables in longer words, and that this difference is most pronounced when comparing monosyllabic words to other words (see e.g. Lehiste 1972 and others cited by Zhang 2002:33). This difference in length between monosyllabic vs. other words has been argued to have phonological consequences: in some languages, for example, contour tones are only licensed in monosyllabic forms (where there is more time for the entire contour to be realized; see Zhang 2002 for discussion). Thus one potential explanation for why Lua prefers to license NC $\tilde{V}$  sequences in long monosyllables is because this is the environment where vowels are the longest.

But is this distributional restriction of NC $\tilde{V}$  sequences what we would expect, given how NCs and nasal vowels pattern more generally in the language? The answer is, unfortunately, unclear. The counts in (65), adapted from Boyeldieu 1985:159, present the frequencies of initial consonant-vowel sequences, arranged by frequency. (I leave out considerations of word length here, as the simplified data in (65) are sufficient to make the point.) As is evident from (65), nasal vowels are generally rare in the language, and short nasal vowels are even rarer.

- (65) Frequencies of consonant-vowel sequences in Lua (Boyeldieu 1985)

<i>Form</i>	<i>Count</i>	<i>Form</i>	<i>Count</i>
CV	310	NCV:	26
CV:	125	C $\tilde{V}$	24
C $\tilde{V}$ :	43	NC $\tilde{V}$ :	4
NCV	29	NC $\tilde{V}$	0

A loglinear model of the count data in (65) reveals that the absence of NC $\tilde{V}$  sequences (as opposed to NC $\tilde{V}$ : sequences) could be due to the confluence of several independent factors: a marked dispreference for NC $\tilde{V}$  sequences (regardless of vowel length), and an additional dispreference for short nasal vowels (regardless of preceding consonant). (For more details on the statistical analysis of

(65), see Appendix B.) The important point here is that, while it may appear from (65) that Lua is a language that straightforwardly bears out the categorical prediction of the contrast-based account – that NC $\tilde{V}$  is licit – we need more data to be able to know whether or not the observed asymmetry can be explained entirely by referencing other factors.

### The role of word length

The appeal above to the role of word length in conditioning the distribution of NC $\tilde{V}$  sequences raises the question as to whether or not languages are more willing to license NC $\tilde{V}$  sequences in monosyllabic words, where the vowel is predicted to be longer, more generally.

While analysis of the four remaining corpora in the study (Day, Nougayrol 1979; Ngambay, Vandame 1974; Ngbaka, Henrix et al. 2015; Vouté, Guarisma 1978) did not reveal any such preferences, limited evidence that languages can be sensitive to the monosyllabic vs. longer distinction comes from corpus counts provided in Hagège's (1970) grammar of Mbum (Niger-Congo). Vowel length is not contrastive in Mbum, and all vowels (both oral and nasal) are transcribed as short. In a presentation of the lexical statistics of his corpus (the corpus itself is not provided in the grammar), Hagège (1970:63–64) notes that 55% of the forms included are monosyllabic. Yet 86% (or 6/7) of the words containing NC $\tilde{V}$  in Hagège's grammar are monosyllabic (e.g. nzá 'balafon [balafon]', p. 59), and the one exception, ngúárá ('*Securidaca longipedunculata*', p. 65) is an anomaly in other ways: nasal vowels are generally confined to word-initial syllables in Mbum (Hagège 1970:57, 60–61; see Chapter 2.3.1), but in this form they appear in non-initial syllables as well.

More data would be necessary to perform an analysis and verify the asymmetry, but it appears, from limited data, that NC $\tilde{V}$  sequences are generally preferred in monosyllabic forms in Mbum.

### 4.7.3 NC $\tilde{V}$ licensing is not sensitive to the contrastive status of NC

The last few sections of this chapter have shown that many languages exhibit a dispreference for NC $\tilde{V}$ . Of the 23 languages surveyed that license N–NC and V– $\tilde{V}$  contrasts, 11 ban the sequences entirely. In addition, even among the languages that allow NC $\tilde{V}$  sequences to surface, in some there is evidence for a gradient dispreference for NC $\tilde{V}$ . In three of the six corpora analyzed (Day, Nougayrol 1979; Mbay, Keegan 1996; Ngbaka, Henrix et al. 2015), NC $\tilde{V}$  sequences are underattested beyond what is expected given the independent rarity of NCs and  $\tilde{V}$ s.

Recall that part of the explanation for why languages disprefer NC $\tilde{V}$  sequences is that the presence of a nasal vowel following NC reduces or eliminates the external cues that render NC maximally distinct from N. Given that the explanation for this particular restriction depends on contrast, we might expect that contrast should also play a role in determining *which* NC $\tilde{V}$  sequences a language should disprefer. In other words, we might expect to find that a language disprefers NC $\tilde{V}$  sequences in environments where NC contrasts with a homorganic N; in environments where NC does not contrast with a homorganic N, however, NC $\tilde{V}$  sequences may be tolerated. The languages identified in the survey allow us to test this hypothesis, as many of them either lack N–NC contrasts at certain places of articulation or neutralize N–NC contrasts at certain positions within the word (in favor of NC). Table 4.7 summarizes known restrictions on the N–NC contrasts for all identified languages that exhibit a dispreference (categorical or gradient) for NC $\tilde{V}$ .

In none of these cases, however, is there any evidence to suggest that restrictions on NC $\tilde{V}$  licensing track restrictions on the distribution of N–NC. In the languages where NC $\tilde{V}$  is banned categorically, it is banned regardless of the identity of NC. In the languages where NC $\tilde{V}$  is gradiently dispreferred, there is no evidence to suggest that NC $\tilde{V}$  is better-tolerated when the NC does not

Table 4.7: Restrictions on N–NC in languages that disprefer NC $\tilde{V}$ 

<i>Language</i>	<i>NC<math>\tilde{V}</math> dispreference</i>	<i>Restriction</i>
Acehnese	Categorical	–
Apinayé	Categorical	–
Gbaya Kara	Categorical	Intervocally, labiovelar NCs do not contrast with Ns
Gbeya	Categorical	–
Ndumbea	Categorical	Labialized velar NCs do not contrast with Ns
Nheengatu	Categorical	Velar NCs do not contrast with Ns
Páez	Categorical	Laminal & velar NCs do not contrast with Ns
Paici	Categorical	Palatal NCs do not contrast with Ns
Saramaccan	Categorical	Velar NCs do not contrast with Ns
Vai	Categorical	–
Day	Gradient	Velar NCs do not contrast with Ns
Mbay	Gradient	Palatal and velar NCs do not contrast with Ns
Ngbaka	Gradient	Word-initially, velar NCs do not contrast with Ns

contrast with a homorganic N. In Day, the three attested NC $\tilde{V}$  sequences involve alveolar and palatal NCs (which contrast with homorganic nasals); for the remaining two cases, Mbay and Ngbaka, loglinear models fit to a revised version of the dictionary data indicate that the contrastive status of NC is not a significant predictor of the language’s willingness to license NC $\tilde{V}$  sequences (see Appendix C for more discussion of these models, and presentation of the results).<sup>24</sup>

These results suggest that while the MINDIST constraints that disprefer NC $\tilde{V}$  sequences may be sensitive to whether or not a language licenses an N–NC contrast, they are not sensitive to restrictions placed on that contrast, either restrictions at the level of the inventory (i.e. the lack of a velar N–NC contrast in many of the languages in Table 4.7) or restrictions at the level of the phonotactics (i.e. contextual neutralization of initial [ŋ–ŋg] in Ngbaka). For further discussion, on both how this finding relates to certain findings in Chapter 3 as well as what these findings might tell us about restrictions on the composition of possible MINDIST constraints, see Chapter 5.2.3.

## 4.8 Summary

In this chapter, I have shown that there exists a significant dispreference for NC $\tilde{V}$  sequences, regardless of whether the nasal vowel is phonemically nasal, or allophonically nasalized by a following nasal consonant. I have argued that a contrast-based approach is the best way to capture this dispreference, as the analysis developed here makes correct predictions regarding asymmetries in the typology, both in the typology of nasal cluster effects, and in the typology of NC $\tilde{V}$  licensing more generally. An important component of the analyses presented here is that the general dispreference for NC $\tilde{V}$  is due to the fact that, whether the vowel is phonemically or allophonically nasalized, constraints on contrast conflict: in NC<sub>1</sub>VNC<sub>2</sub> sequences it is impossible to simultaneously render

<sup>24</sup>In addition, I checked the corpora for the three remaining languages (Lua, Ngambay, and Vouté) that do not exhibit a gradient dispreference for NC $\tilde{V}$ , to make sure that a potential dispreference for NC $\tilde{V}$  in environments where NC contrasts with a homorganic nasal consonant was not washed out by a permissiveness for NC $\tilde{V}$  in environments where NC does not. In Lua and Ngambay, the *only* attested tokens of NC $\tilde{V}$  involve an NC that contrasts with a homorganic N. In Vouté, a loglinear model indicates that there is no dispreference for NC $\tilde{V}$ , regardless of whether or not the NC contrasts with a homorganic N. For details on this model, see Appendix C.

N–NC and C–NC maximally distinct, and in  $NC\tilde{V}$  it is impossible to simultaneously render N–NC and V– $\tilde{V}$  maximally distinct. The fact that conflicts among constraints on contrast can have observable consequences is expected, given the broader argument of this study: that constraints on the distribution of NCs are constraints on contrast.

## 4.9 Appendix A: summary of the NC<sub>1</sub>VNC<sub>2</sub> survey

The list of languages included in the nasal cluster effects survey is provided below. Note that in the cases where there are two sources cited, the first citation is for information about nasal cluster effects, while the second citation is for information about the language's vocalic inventory. The repairs are abbreviated in the following way: NC<sub>1</sub>-N = NC<sub>1</sub> nasalization, NC<sub>2</sub>-N = NC<sub>2</sub> nasalization, NC<sub>1</sub>-O = NC<sub>1</sub> oralization, NC<sub>2</sub>-O = NC<sub>2</sub> oralization, ?? = no evidence which repair is utilized. For the "Repaired structures" columns, if a cell is shaded, it means that the language listed in that row repairs the structure in that column. It is important to note that in many cases the descriptions of patterns presented below are simplifications of descriptions provided in the cited sources. While these simplifications are non-crucial for the present purposes, any readers wishing to rely on this survey for future work are strongly encouraged to consult the original sources.

Table 4.8: Appendix for the nasal cluster effects survey

Repair	Name Source	Repaired structures NC <sub>1</sub> VNC <sub>2</sub> NC <sub>1</sub> VN <sub>2</sub>		Restrictions	V- $\tilde{V}$ ?
NC <sub>1</sub> -N	Bangubangu (Niger-Congo) Meeussen 1963 McCawley 1973			Velar ND <sub>1</sub>	?
NC <sub>1</sub> -N	Bemba (Niger-Congo) Meeussen 1963 Kim 1999			ND <sub>1</sub>	No
NC <sub>1</sub> -N	Bobangi (Niger-Congo) Meeussen 1963 Whitehead 1964			Mostly velar ND <sub>1</sub>	No
NC <sub>1</sub> -N	Bokote (Niger-Congo) Meeussen 1963			Isolated examples	?
NC <sub>1</sub> -N	Bolia (Niger-Congo) Meeussen 1963 Mamet 1960			Palatal ND <sub>1</sub>	No
NC <sub>1</sub> -N	Budya (Niger-Congo) Meeussen 1963			Velar ND <sub>1</sub>	?
NC <sub>1</sub> -N	Buyu Meeussen 1963			Velar ND <sub>1</sub>	?
NC <sub>1</sub> -N	Caga Meeussen 1963			Mostly velar ND <sub>1</sub>	?
NC <sub>1</sub> -N	Dayak Herbert 1977 Blust 2012			<i>none listed</i>	No
NC <sub>1</sub> -N	Ganda Meeussen 1963 Kamoga & Stevick 1968			All but alveolar ND <sub>1</sub>	No
NC <sub>1</sub> -N	Gikuyu Meeussen 1963 Armstrong 1967			All but alveolar ND <sub>1</sub>	No

Repair	Name Source	Repaired structures NC <sub>1</sub> VNC <sub>2</sub> NC <sub>1</sub> VN <sub>2</sub>	Restrictions	V- $\tilde{V}$ ?
NC <sub>1</sub> -N	Gwamba-Thonga Meeussen 1963		Velar ND <sub>1</sub>	?
NC <sub>1</sub> -N	Hemba Meeussen 1963 Vandermeiren 1912		<i>none listed</i>	No
NC <sub>1</sub> -N	Ila Meeussen 1963 Smith 1907		<i>none listed</i>	No
NC <sub>1</sub> -N	Kami Meeussen 1963		Mostly velar ND <sub>1</sub>	?
NC <sub>1</sub> -N	Kaonde Meeussen 1963		Mostly velar ND <sub>1</sub>	?
NC <sub>1</sub> -N	Kerebe Meeussen 1963 Thornell 2008		Certain roots only	No
NC <sub>1</sub> -N	Kok-Kaper Jones 2000		<i>none listed</i>	?
NC <sub>1</sub> -N	Kuria Meeussen 1963 Cammenga 2004		Velar ND <sub>1</sub>	No
NC <sub>1</sub> -N	Lamba Meeussen 1963		Optional in verbs	?
NC <sub>1</sub> -N	Luba-Katanga Meeussen 1963 Theuws 1954		Many exceptions	No
NC <sub>1</sub> -N	Lumasaamba Herbert 1977 Brown 1972		All but alveolar ND <sub>1</sub>	No
NC <sub>1</sub> -N	Makonde Meeussen 1963 Odden 1990		Mostly velar ND <sub>1</sub>	No
NC <sub>1</sub> -N	Matumbi Meeussen 1963 Odden 1996		Mostly velar ND <sub>1</sub>	No
NC <sub>1</sub> -N	Mwanga Meeussen 1963		Velar ND <sub>1</sub>	?
NC <sub>1</sub> -N	Myene Meeussen 1963 Rékanga 2014		Alveolar & velar ND <sub>1</sub>	No
NC <sub>1</sub> -N	Ngaju Dayak Blust 2012		Dependent on PoA; see 4.3.2	No

Repair	Name Source	Repaired structures NC <sub>1</sub> VNC <sub>2</sub> NC <sub>1</sub> VN <sub>2</sub>	Restrictions	V-Ũ?
NC <sub>1</sub> -N	Nilamba Meeussen 1963 Yukawa 1989		Not palatal/velar ND <sub>1</sub>	No
NC <sub>1</sub> -N	Nkore Meeussen 1963 Taylor 1998		Certain roots only	No
NC <sub>1</sub> -N	Ntomba Meeussen 1963 Mamet 1955		<i>none listed</i>	No
NC <sub>1</sub> -N	Nyamwezi Meeussen 1963 Maganga & Schadeberg 1992		Mostly velar ND <sub>1</sub>	No
NC <sub>1</sub> -N	Nyiha Meeussen 1963 Busse 1960		Mostly velar ND <sub>1</sub>	No
NC <sub>1</sub> -N	Nyoro Meeussen 1963 Rubongoya 1999		Certain roots only	No
NC <sub>1</sub> -N	Ombo Meeussen 1952, 1963 Jacobs 1964		Certain prefixes only	No
NC <sub>1</sub> -N	Rundi Meeussen 1963 Rodegem 1967		Certain roots only	No
NC <sub>1</sub> -N	Rwanda Meeussen 1963 Kimenye 2002		Certain roots only	No
NC <sub>1</sub> -N	Sanga Meeussen 1963		<i>none listed</i>	?
NC <sub>1</sub> -N	Sango Meeussen 1963 Samarin 1967		Mostly velar ND <sub>1</sub>	Yes
NC <sub>1</sub> -N	Shambala Meeussen 1963 Besha 1989		Velar ND <sub>1</sub>	No
NC <sub>1</sub> -N	Soli Meeussen 1963		<i>none listed</i>	?
NC <sub>1</sub> -N	Suthu Meeussen 1963 Louwrens et al. 1995		Velar ND <sub>1</sub>	No
NC <sub>1</sub> -N	Swahili Meeussen 1963 Mpiranya 2015		Velar ND <sub>1</sub>	No

Repair	Name (Family) Source	Repaired structures NC <sub>1</sub> VNC <sub>2</sub> NC <sub>1</sub> VN <sub>2</sub>		Restrictions	V-Ũ?
NC <sub>1</sub> -N	Tabwa Meeussen 1963 van Acker 1907			Many exceptions	No
NC <sub>1</sub> -N	Taita Meeussen 1963			Mostly velar ND <sub>1</sub>	?
NC <sub>1</sub> -N	Tetela Meeussen 1963 Jacobs 1964			NC <sub>2</sub> required in nouns	No
NC <sub>1</sub> -N	Vira Meeussen 1963			Mostly velar ND <sub>1</sub>	?
NC <sub>1</sub> -N	Yaunde Meeussen 1963 Essono 2000			Some prefixes only	No
NC <sub>1</sub> -N	Zande Herbert 1977 Boyd 1995			ND <sub>1</sub> , variably	No
NC <sub>1</sub> -N	Ziba Meeussen 1963			Certain roots only	?
NC <sub>2</sub> -N	Gurindji McConvell 1988			Western dialects only	No
NC <sub>1</sub> /NC <sub>2</sub> -O	Mori Bawah Esser & Mead 2011 Blust 2012			Voiceless NC <sub>2</sub>	No
NC <sub>1</sub> -O	Timugon Murut Blust 2012			<i>none listed</i>	No
NC <sub>2</sub> -O	Arabana Hercus 1994			Retroflex NC <sub>2</sub>	No
NC <sub>2</sub> -O	Bilinara McConvell 1988			Homorganic NC <sub>2</sub>	No
NC <sub>2</sub> -O	Djaru McConvell 1988 Tsunoda 1981			Palatal/velar NC <sub>2</sub>	No
NC <sub>2</sub> -O	Gooniyandi McConvell 1988 McGregor 1990			Homorganic NC <sub>2</sub>	No
NC <sub>2</sub> -O	Gurindji McConvell 1988			Certain suffixes	No
NC <sub>2</sub> -O	Kalkatungu McConvell 1988 Blake 1979			Certain suffixes	No
NC <sub>2</sub> -O	Kwanyama Herbert 1977			All ND <sub>2</sub> s but velar	No
NC <sub>2</sub> -O	Mudbura McConvell 1988			Homorganic NC <sub>2</sub>	No



Repair	Name (Family) Source	Repaired structures NC <sub>1</sub> VNC <sub>2</sub> NC <sub>1</sub> VN <sub>2</sub>		Restrictions	V- $\tilde{V}$ ?
NC <sub>2</sub> -O	Ndonga Herbert 1977 Fivaz 1986			Alveolar ND <sub>2</sub>	No
NC <sub>2</sub> -O	Ngarinyman McConvell 1988			Homorganic NC <sub>2</sub>	?
NC <sub>2</sub> -O	Ngazija Herbert 1977			All ND <sub>2</sub> s but velar	?
NC <sub>2</sub> -O	Nhanda Blust 2012 Blevins 2001			Homorganic NC <sub>1</sub>	No
NC <sub>2</sub> -O	Yindjibarndi Wordick 1982			All NC <sub>2</sub> but alveolar	No
??	Saramaccan McWhorter & Good 2012			<i>none listed</i>	Yes

## 4.10 Appendix B: Summary of statistical analyses

This appendix describes the corpora used to investigate cross-linguistic patterns of NC $\tilde{V}$  licensing, and provides summaries of the statistical analyses done to investigate them. All statistical analyses described in this section use the glm function of R's lme4 package; Bates & Maechler 2011.

### 4.10.1 Day (Niger-Congo) corpus and analysis

#### Corpus

The Day counts (66) were obtained from a lexicon provided by Nougayrol (1979), which contained 3599 consonant-vowel sequences from 1913 words. Words were hand-transcribed into a text file, and analysis of these words into CV sequences was automated with a Python script. The factors investigated included *consonant identity*, *vowel identity*, and *word length* (monosyllabic, notated as  $X_{1\sigma}$  vs. longer, notated as  $X$ ).

(66) Frequencies of consonant-vowel sequences in Day (Nougayrol 1979)

<i>Form</i>	<i>Count</i>	<i>Form</i>	<i>Count</i>
CV	2563	C $\tilde{V}_{1\sigma}$	55
CV <sub>1<math>\sigma</math></sub>	533	NCV <sub>1<math>\sigma</math></sub>	27
NCV	355	NC $\tilde{V}_{1\sigma}$	2
C $\tilde{V}$	63	NC $\tilde{V}$	1

#### Analysis (Table 4.9)

*Factors:* consonant identity (C vs. NC); vowel quality (V vs.  $\tilde{V}$ ); word length ( $1\sigma$  vs.  $2\sigma+$ ). Factors were dummy-coded and the unmarked options (C, V, and  $2\sigma+$ ) were treated as the baseline values.

*Notes on interpretation:* interactions are indicated with an asterisk (\*). An effect is considered significant if  $p \leq .05$  (roughly, if the Z-Statistic  $\geq |2|$ ), as assessed by the Wald test. A factor or

interaction with a negative coefficient means that the structure is less frequent; a factor or interaction with a positive coefficient means that the structure is more frequent.

Table 4.9: Appendix B: results of statistical analysis for Day

Factor	Coefficient	Z-Statistic	Significant?
Intercept	7.85		
NC	-1.98	-34.91	Yes ( $p < .001$ )
$1\sigma$	-1.57	-32.99	Yes ( $p < .001$ )
$\tilde{V}$	-3.71	-29.06	Yes ( $p < .001$ )
NC* $1\sigma$	-0.29	-1.93	Trending ( $p = .053$ )
NC* $\tilde{V}$	-2.17	-2.15	Yes ( $p < .05$ )
$1\sigma$ * $\tilde{V}$	0.72	3.08	Yes ( $p < .01$ )
NC* $1\sigma$ * $\tilde{V}$	1.83	1.46	No ( $p > .05$ )

## Summary

The apparent preference for NC $\tilde{V}$  $1\sigma$  over NC $\tilde{V}$  could be due to a confluence of independent factors.

## 4.10.2 Lua (Niger-Congo) corpus and analysis

### Corpus

The Lua counts (67) were obtained consulting the counts available in Boyeldieu's (1985) grammar, on p. 159. These counts include only initial consonant-vowel sequences, as initial position is the only place where NCs contrast with other consonants, and  $\tilde{V}$ s contrast with Vs. To keep the analysis relatively simple, only *consonant identity*, *vowel identity*, and *vowel length* were investigated (incorporating considerations of word length, i.e. monosyllabic vs. longer, does not change the results of the analysis in any noticeable way).

(67) Frequencies of initial consonant-vowel sequences in Lua (Boyeldieu 1985:159)

Form	Count	Form	Count
CV	310	NCV:	26
CV:	125	C $\tilde{V}$	24
C $\tilde{V}$ :	43	NC $\tilde{V}$ :	4
NCV	29	NC $\tilde{V}$	0

### Analysis (Table 4.10)

*Factors:* consonant identity (C vs. NC); vowel quality (V vs.  $\tilde{V}$ ); vowel length (V vs. V:). Factors were dummy-coded and the unmarked options (C, V, and V) were treated as the baseline values.

*Notes on interpretation:* interactions are indicated with an asterisk (\*). An effect is considered significant if  $p \leq .05$  (roughly, if the Z-Statistic  $\geq |2|$ ), as assessed by the Wald test. A factor or interaction with a negative coefficient means that the structure is less frequent; a factor or interaction with a positive coefficient means that the structure is more frequent.

Table 4.10: Appendix B: results of statistical analysis for Lua

Factor	Coefficient	Z-Statistic	Significant?
Intercept	5.04		
NC	-2.37	-12.20	Yes ( $p < .001$ )
V:	-0.89	-8.47	Yes ( $p < .001$ )
$\tilde{V}$	-2.56	-12.08	Yes ( $p < .001$ )
NC*V:	0.78	2.70	Yes ( $p < .01$ )
NC* $\tilde{V}$	-17.24	-0.01	No ( $p > .05$ )
V:* $\tilde{V}$	1.48	5.35	Yes ( $p < .001$ )
NC*V:* $\tilde{V}$	16.45	0.01	No ( $p > .05$ )

### Summary

The apparent preference for NC $\tilde{V}$ : over NC $\tilde{V}$  could be due to a confluence of independent factors. (Note that the high coefficients for NC\* $\tilde{V}$  and NC\*V:\* $\tilde{V}$  are likely due to the fact that there is a zero (entered as  $10^{-8}$  for the analysis) in the count data.

### 4.10.3 Mbay (Nilo-Saharan) corpus and analysis

#### Corpus

The Mbay counts (68) were obtained from Keegan's (1996) dictionary of the language (containing 11,544 consonant-vowel sequences, from 5,558 words). Words were hand-transcribed into a text file, and analysis of these words into CV sequences was automated with a Python script. To keep the analysis relatively simple, only *consonant identity*, *vowel identity*, and *vowel length* were investigated.

(68) Frequencies of consonant-vowel sequences in Mbay (Keegan 1996)

<i>Form</i>	<i>Count</i>	<i>Form</i>	<i>Count</i>
CV	8185	NCV:	259
CV:	1300	C $\tilde{V}$	153
NCV	1243	NC $\tilde{V}$ :	52
C $\tilde{V}$ :	344	NC $\tilde{V}$	8

#### Analysis (Table 4.11)

*Factors:* consonant identity (C vs. NC); vowel quality (V vs.  $\tilde{V}$ ); vowel length (V vs. V:). Factors were dummy-coded and the unmarked options (C, V, and V) were treated as the baseline values.

*Notes on interpretation:* interactions are indicated with an asterisk (\*). An effect is considered significant if  $p \leq .05$  (roughly, if the Z-Statistic  $\geq |2|$ ), as assessed by the Wald test. A factor or interaction with a negative coefficient means that the structure is less frequent; a factor or interaction with a positive coefficient means that the structure is more frequent.

Table 4.11: Appendix B: results of statistical analysis for Mbay

Factor	Coefficient	Z-Statistic	Significant?
Intercept	9.01		
NC	-1.88	-61.92	Yes ( $p < .001$ )
V:	-1.84	-61.63	Yes ( $p < .001$ )
$\tilde{V}$	-3.98	-48.77	Yes ( $p < .001$ )
NC*V:	0.27	3.64	Yes ( $p < .001$ )
NC* $\tilde{V}$	-1.07	-2.93	Yes ( $p < .01$ )
V:* $\tilde{V}$	2.65	26.07	Yes ( $p < .001$ )
NC*V:* $\tilde{V}$	0.79	1.98	Yes ( $p < .05$ )

### Summary

A preference for NC $\tilde{V}$ : over NC $\tilde{V}$  emerges in Mbay even when distributional asymmetries of the relevant segment types (consonant identity, vowel quality, and vowel length) are controlled for.

## 4.10.4 Ngambay (Nilo-Saharan) corpus and analysis

### Corpus

The Ngambay counts (69) were obtained from a lexicon provided by Vandame (1974), which contained 1018 consonant-vowel sequences from 834 words. Words were hand-transcribed into a text file, and analysis of these words into CV sequences was automated with a Python script. The factors investigated included *consonant identity*, *vowel identity*, and *word length* (monosyllabic, notated as  $X_{1\sigma}$  vs. longer, notated as  $X$ ).

(69) Frequencies of consonant-vowel sequences in Ngambay (Vandame 1974)

<i>Form</i>	<i>Count</i>	<i>Form</i>	<i>Count</i>
CV	536	C $\tilde{V}_{1\sigma}$	23
CV $_{1\sigma}$	286	NC $\tilde{V}_{1\sigma}$	6
NCV $_{1\sigma}$	100	C $\tilde{V}$	2
NCV	65	NC $\tilde{V}$	0

### Analysis (Table 4.12)

*Factors:* consonant identity (C vs. NC); vowel quality (V vs.  $\tilde{V}$ ); word length ( $1\sigma$  vs.  $2\sigma+$ ). Factors were dummy-coded and the unmarked options (C, V, and  $2\sigma+$ ) were treated as the baseline values.

*Notes on interpretation:* interactions are indicated with an asterisk (\*). An effect is considered significant if  $p \leq .05$  (roughly, if the Z-Statistic  $\geq |2|$ ), as assessed by the Wald test. A factor or interaction with a negative coefficient means that the structure is less frequent; a factor or interaction with a positive coefficient means that the structure is more frequent.

### Summary

The apparent preference for NC $\tilde{V}_{1\sigma}$  over NC $\tilde{V}$  could be due to a confluence of independent factors. Note that the high coefficients for NC\* $\tilde{V}$  and NC\* $1\sigma$ \* $\tilde{V}$  are likely due to the fact that there is a zero (entered as  $10^{-8}$  for the analysis) in the count data.

Table 4.12: Appendix B: results of statistical analysis for Ngambay

Factor	Coefficient	Z-Statistic	Significant?
Intercept	6.10		
NC	-1.68	-15.41	Yes ( $p < .001$ )
$1\sigma$	-0.63	-8.58	Yes ( $p < .05$ )
$\tilde{V}$	-5.59	-7.89	Yes ( $p < .001$ )
NC* $1\sigma$	0.20	1.13	No ( $p > .05$ )
NC* $\tilde{V}$	-17.43	-0.00	No ( $p > .05$ )
$1\sigma$ * $\tilde{V}$	3.07	4.15	Yes ( $p < .001$ )
NC* $1\sigma$ * $\tilde{V}$	17.56	0.00	No ( $p > .05$ )

#### 4.10.5 Ngbaka (Niger-Congo) corpus and analysis

##### Corpus

The Ngbaka counts (70) were obtained from a dictionary provided by Henrix et al. (2015), which contained 13,696 consonant-vowel sequences from 5,571 words. Words were hand-transcribed into a text file, and analysis of these words into CV sequences was automated with a Python script. The factors investigated included *consonant identity*, *vowel identity*, and *word length* (monosyllabic, notated as  $X_{1\sigma}$  vs. longer, notated as  $X$ ).

(70) Frequencies of consonant-vowel sequences in Ngbaka (Henrix et al. 2015)

<i>Form</i>	<i>Count</i>	<i>Form</i>	<i>Count</i>
CV	10190	$C\tilde{V}_{1\sigma}$	122
NCV	2296	$NCV_{1\sigma}$	90
$C\tilde{V}$	634	$NC\tilde{V}$	28
$CV_{1\sigma}$	334	$NC\tilde{V}_{1\sigma}$	2

##### Analysis (Table 4.13)

*Factors:* consonant identity (C vs. NC); vowel quality (V vs.  $\tilde{V}$ ); word length ( $1\sigma$  vs.  $2\sigma+$ ). Factors were dummy-coded and the unmarked options (C, V, and  $2\sigma+$ ) were treated as the baseline values.

*Notes on interpretation:* interactions are indicated with an asterisk (\*). An effect is considered significant if  $p \leq .05$  (roughly, if the Z-Statistic  $\geq |2|$ ), as assessed by the Wald test. A factor or interaction with a negative coefficient means that the structure is less frequent; a factor or interaction with a positive coefficient means that the structure is more frequent.

##### Summary

The apparent preference for  $NC\tilde{V}_{1\sigma}$  over  $NC\tilde{V}$  could be due to a confluence of independent factors.

#### 4.10.6 Vouté (Niger-Congo) corpus and analysis

##### Corpus

The Vouté counts (71) were obtained from a lexicon provided by Guarisma (1978), which contained 1908 consonant-vowel sequences from 1067 words. Words were hand-transcribed into a text file, and analysis of these words into CV sequences was automated with a Python script. The factors

Table 4.13: Appendix B: results of statistical analysis for Ngbaka

Factor	Coefficient	Z-Statistic	Significant?
Intercept	9.23		
NC	-1.49	-64.51	Yes ( $p < .001$ )
$1\sigma$	-3.42	-61.47	Yes ( $p < .001$ )
$\tilde{V}$	-2.78	-67.85	Yes ( $p < .001$ )
NC* $1\sigma$	0.18	1.48	No ( $p > .05$ )
NC* $\tilde{V}$	-1.63	-8.38	Yes ( $p < .001$ )
$1\sigma$ * $\tilde{V}$	1.77	15.60	Yes ( $p < .001$ )
NC* $1\sigma$ * $\tilde{V}$	-1.17	-1.56	No ( $p > .05$ )

investigated included *consonant identity*, *vowel identity*, and *word length* (monosyllabic, notated as  $X_{1\sigma}$  vs. longer, notated as  $X$ ).

(71) Frequencies of consonant-vowel sequences in Vouté (Vandame 1974)

Form	Count	Form	Count
CV	1273	C $\tilde{V}_{1\sigma}$	37
CV $_{1\sigma}$	323	C $\tilde{V}$	23
NCV	155	NC $\tilde{V}_{1\sigma}$	21
NCV $_{1\sigma}$	71	NC $\tilde{V}$	5

#### Analysis (Table 4.14)

*Factors:* consonant identity (C vs. NC); vowel quality (V vs.  $\tilde{V}$ ); word length ( $1\sigma$  vs.  $2\sigma+$ ). Factors were dummy-coded and the unmarked options (C, V, and  $2\sigma+$ ) were treated as the baseline values.

*Notes on interpretation:* interactions are indicated with an asterisk (\*). An effect is considered significant if  $p \leq .05$  (roughly, if the Z-Statistic  $\geq |2|$ ), as assessed by the Wald test. A factor or interaction with a negative coefficient means that the structure is less frequent; a factor or interaction with a positive coefficient means that the structure is more frequent.

Table 4.14: Appendix B: results of statistical analysis for Vouté

Factor	Coefficient	Z-Statistic	Significant?
Intercept	7.15		
NC	-2.11	-24.75	Yes ( $p < .001$ )
$1\sigma$	-1.37	-22.01	Yes ( $p < .001$ )
$\tilde{V}$	-4.01	-19.08	Yes ( $p < .001$ )
NC* $1\sigma$	0.59	3.78	Yes ( $p < .001$ )
NC* $\tilde{V}$	0.58	1.16	No ( $p > .05$ )
$1\sigma$ * $\tilde{V}$	1.85	6.78	Yes ( $p < .001$ )
NC* $1\sigma$ * $\tilde{V}$	0.37	0.63	No ( $p > .05$ )

#### Summary

The apparent preference for NC $\tilde{V}_{1\sigma}$  over NC $\tilde{V}$  could be due to a confluence of independent factors.

## 4.11 Appendix C: Summary of additional statistical analyses

The statistical analyses in Appendix B do not take into account the fact that, in many of the languages that license N–NC and V– $\tilde{V}$ , NCs are not phonemically contrastive with Ns at all places of articulation or in all contexts. The more complex analyses presented in this appendix attempt to discern whether or not languages are more likely to license NC $\tilde{V}$  sequences in contexts where NC does not contrast with a homorganic N.

This section focuses on the six languages with available corpora that allow NC $\tilde{V}$ , as in the cases where NC $\tilde{V}$  is categorically banned it is clear that the ban extends to all NCs, whether or not they contrast with a homorganic N. In three of these (Day, Lua, and Ngambay), the only tokens of NC $\tilde{V}$  involve NCs that *do* phonemically contrast with a homorganic N. As such, it is fairly obvious that these languages do not avoid NC $\tilde{V}$  sequences in contexts where NC contrasts with a homorganic N. In what follows I present analyses for the remaining three languages (Mbay, Ngbaka, and Vouté) where the generalization, from the raw numbers, is less clear. To preview the results, in no case does the contrastive status of NC affect its ability to precede  $\tilde{V}$ . As before, all analyses described in this section use the glm function or R’s lme4 package (Bates & Maechler 2011).

In the original analyses (see Appendix B), the predictor “NC” differentiated those CV sequences that contain an NC from those CV sequences that do not. In the revised analysis, “NC” was replaced with a new predictor, “Contrast”, which allows the analysis to differentiate NCs that contrast with a homorganic N from those that do not. “Contrast”, unlike “NC”, is a three-way predictor: NCs that contrast with a homorganic NC were assigned a value of “yes”, NCs that do not contrast with a homorganic NC were assigned a value of “no”, and Cs (for which the issue of contrast is irrelevant) were assigned a value of “n.a.”.

### 4.11.1 Further analysis of Mbay

In Mbay, bilabial and alveolar NCs contrast with a homorganic N; palatal and velar NCs do not. The table in (72) takes this distinction into consideration, providing revised frequency counts, the factors used, and their values. For V: and  $\tilde{V}$ , a value of 1 indicates the presence of that structure, and a value of 0 indicates its absence.

(72) Revised frequency counts for Mbay

<i>Form</i>	<i>Count</i>	<i>V:</i>	<i><math>\tilde{V}</math></i>	<i>Contrast</i>	<i>Form</i>	<i>Count</i>	<i>V:</i>	<i><math>\tilde{V}</math></i>	<i>Contrast</i>
CV	8185	0	0	n.a.	C $\tilde{V}$	153	0	1	n.a.
CV:	1300	1	0	n.a.	NCV:	84	1	0	no
NCV	698	0	0	no	NC $\tilde{V}$ :	29	1	1	yes
NCV	545	0	0	yes	NC $\tilde{V}$ :	23	1	1	no
C $\tilde{V}$ :	344	1	1	n.a.	NC $\tilde{V}$	6	0	1	no
NCV:	175	1	0	yes	NC $\tilde{V}$	2	0	1	yes

For the analysis, all binary factors were dummy-coded (with the marked values, V: and  $\tilde{V}$ , as the default values). The “Count” factor was helmert-coded, so as to compare the behavior of Cs vs. NCs (this comparison notated in the results as NC<sub>Present</sub>), and the behavior of NCs that contrast with homorganic Ns vs. those that don’t (this comparison notated in the results as NC<sub>Contrast</sub>). The model results are summarized in Table 4.15. The factors whose coefficients and significance values are marked with a em dash (or –) are not defined due to singularities.

Table 4.15: Appendix C: results of statistical analysis for Mbay

	Factor	Coefficient	Z-Statistic	Significant?
a.	Intercept	7.06	–	–
b.	$\tilde{V}$	-4.00	-14.64	Yes ( $p < .001$ )
c.	$V_i$	-1.63	-22.51	Yes ( $p < .001$ )
d.	$NC_{Contrast}$	-0.12	-4.33	Yes ( $p < .001$ )
e.	$NC_{Present}$	-0.64	-62.43	Yes ( $p < .001$ )
f.	$\tilde{V} * V_i$	3.64	8.31	Yes ( $p < .001$ )
g.	$\tilde{V} * NC_{Contrast}$	-0.43	-1.04	No ( $p > .05$ )
h.	$\tilde{V} * NC_{Present}$	-1.18	-8.68	Yes ( $p < .001$ )
i.	$V_i * NC_{Contrast}$	0.49	6.79	Yes ( $p < .001$ )
j.	$V_i * NC_{Present}$	–	–	–
k.	$\tilde{V} * V_i * NC_{Contrast}$	0.17	0.40	No ( $p > .05$ )
l.	$\tilde{V} * V_i * NC_{Contrast}$	–	–	–

For our purposes, the effect of interest is the  $\tilde{V} * NC_{Contrast}$  interaction in (g). The fact that the interaction is not significant indicates that the frequency of  $NC\tilde{V}$  sequences does not depend on whether or not NC contrasts with a homorganic N.

#### 4.11.2 Further analysis of Ngbaka

In Ngbaka, NCs contrast with a homorganic N in most positions, except word-initially, where [ŋg] but not [ŋ] is permitted. The table in (73) takes this distinction into consideration, providing revised frequency counts, the factors used, and their values. For  $V_i$  and  $\tilde{V}$ , a value of 1 indicates the presence of that structure, and a value of 0 indicates its absence.

(73) Revised frequency counts for Ngbaka

Form	Count	$1\sigma$	$\tilde{V}$	Contrast	Form	Count	$1\sigma$	$\tilde{V}$	Contrast
CV	10190	0	0	n.a.	$NCV_{1\sigma}$	74	1	0	yes
NCV	2063	0	0	yes	$NC\tilde{V}$	23	0	1	yes
$C\tilde{V}$	634	0	1	n.a.	$NCV_{1\sigma}$	16	1	0	no
$CV_{1\sigma}$	334	1	0	n.a.	$NC\tilde{V}$	5	0	1	no
NCV	233	0	0	no	$NC\tilde{V}_{1\sigma}$	1	1	1	no
$C\tilde{V}_{1\sigma}$	122	1	1	n.a.	$NC\tilde{V}_{1\sigma}$	1	1	1	yes

For the analysis, all binary factors were dummy-coded (with the marked values,  $1\sigma$  and  $\tilde{V}$ , as the default values). The “Count” factor was helmert-coded, so as to compare the behavior of Cs vs. NCs (this comparison notated in the results as  $NC_{Present}$ ), and the behavior of NCs that contrast with homorganic Ns vs. those that don’t (this comparison notated in the results as  $NC_{Contrast}$ ). The model results are summarized in Table 4.16.

For our purposes, the effect of interest is the  $\tilde{V} * NC_{Contrast}$  interaction in (g). The fact that the interaction is not significant indicates that the frequency of  $NC\tilde{V}$  sequences does not depend on whether or not NC contrasts with a homorganic N.



Table 4.16: Appendix C: results of statistical analysis for Ngbaka

	Factor	Coefficient	Z-Statistic	Significant?
a.	Intercept	7.44	–	–
b.	$\tilde{V}$	-3.70	-22.23	Yes ( $p < .001$ )
c.	$1\sigma$	-3.14	-32.54	Yes ( $p < .001$ )
d.	$NC_{Contrast}$	1.09	31.56	Yes ( $p < .001$ )
e.	$NC_{Present}$	-0.89	-74.77	Yes ( $p < .001$ )
f.	$\tilde{V} * 1\sigma$	1.01	1.98	Yes ( $p < .05$ )
g.	$\tilde{V} * NC_{Contrast}$	-0.33	-1.31	No ( $p > .05$ )
h.	$\tilde{V} * NC_{Present}$	-0.46	-5.51	Yes ( $p < .001$ )
i.	$1\sigma * NC_{Contrast}$	-0.32	-2.29	Yes ( $p < .05$ )
j.	$1\sigma * NC_{Present}$	0.14	2.72	Yes ( $p < .01$ )
k.	$\tilde{V} * 1\sigma * NC_{Contrast}$	-0.44	-0.58	No ( $p > .05$ )
l.	$\tilde{V} * 1\sigma * NC_{Present}$	-0.38	-1.48	No ( $p > .05$ )

### 4.11.3 Further analysis of Vouté

In Vouté, velar NCs do not contrast with a homorganic N, but NCs at other places of articulation do. The table in (74) takes this distinction into consideration, providing revised frequency counts, the factors used, and their values. For  $V$ : and  $\tilde{V}$ , a value of 1 indicates the presence of that structure, and a value of 0 indicates its absence.

(74) Revised frequency counts for Vouté

<i>Form</i>	<i>Count</i>	<i>1σ</i>	<i><math>\tilde{V}</math></i>	<i>Contrast</i>	<i>Form</i>	<i>Count</i>	<i>1σ</i>	<i><math>\tilde{V}</math></i>	<i>Contrast</i>
CV	1273	0	0	n.a.	$NCV_{1\sigma}$	25	1	0	no
$CV_{1\sigma}$	323	1	0	n.a.	$C\tilde{V}$	23	0	1	n.a.
NCV	114	0	0	yes	$NC\tilde{V}_{1\sigma}$	13	1	1	yes
$NCV_{1\sigma}$	46	1	0	yes	$NC\tilde{V}_{1\sigma}$	8	1	1	no
NCV	41	0	0	no	$NC\tilde{V}$	5	0	1	yes
$C\tilde{V}_{1\sigma}$	37	1	1	n.a.	$NC\tilde{V}$	0	0	1	no

For the analysis, all binary factors were dummy-coded (with the marked values,  $V$ : and  $\tilde{V}$ , as the default values). The “Count” factor was helmert-coded, so as to compare the behavior of Cs vs. NCs (this comparison notated in the results as  $NC_{Present}$ ), and the behavior of NCs that contrast with homorganic Ns vs. those that don’t (this comparison notated in the results as  $NC_{Contrast}$ ). The model results are summarized in Table 4.17.

For our purposes, the effect of interest is the  $\tilde{V} * NC_{Contrast}$  interaction in (g). The fact that the interaction is not significant indicates that the frequency of  $NC\tilde{V}$  sequences does not depend on whether or not NC contrasts with a homorganic N. It is worth noting, however, that the model struggled to fit the data, given the low counts overall and the presence of a 0 (entered as  $10^{-8}$  for the analysis). While the coefficient estimates appear reasonable, the standard error for some of the factors (b, f–h, k–l) were over 1000.

Table 4.17: Appendix C: results of statistical analysis for Vouté

	<b>Factor</b>	<b>Coefficient</b>	<b>Z-Statistic</b>	<b>Significant?</b>
a.	Intercept	5.20	—	—
b.	$\tilde{V}$	-9.76	-0.00	No ( $p > .05$ )
c.	$1\sigma$	-0.92	-8.83	Yes ( $p < .001$ )
d.	$NC_{\text{Contrast}}$	0.51	5.61	Yes ( $p < .001$ )
e.	$NC_{\text{Present}}$	-0.97	-30.70	Yes ( $p < .001$ )
f.	$\tilde{V} * 1\sigma$	8.23	0.00	No ( $p > .05$ )
g.	$\tilde{V} * NC_{\text{Contrast}}$	9.50	0.00	No ( $p > .05$ )
h.	$\tilde{V} * NC_{\text{Present}}$	-2.87	-0.00	No ( $p > .05$ )
i.	$1\sigma * NC_{\text{Contrast}}$	-0.21	-1.34	No ( $p > .05$ )
j.	$1\sigma * NC_{\text{Present}}$	0.22	4.04	Yes ( $p < .001$ )
k.	$\tilde{V} * 1\sigma * NC_{\text{Contrast}}$	-9.56	-0.00	No ( $p > .05$ )
l.	$\tilde{V} * 1\sigma * NC_{\text{Contrast}}$	-3.19	-0.00	No ( $p > .05$ )

## Chapter 5

# Summary and Conclusions

We have seen throughout this study that a contrast-based approach to phonotactics is capable of correctly predicting a number of non-trivial typological asymmetries regarding the distribution of nasal-stop sequences – segments and clusters, underlying and derived. Confirmation for the approach comes from the breadth of the predictions, as well as their specificity.

Regarding the breadth of predictions: there are places in the study where it is shown that multiple empirical generalizations can be predicted by the same phonetic asymmetry. For example, in Chapter 3 we saw that if a language licenses shielding in the heterosyllabic anticipatory context ( $V]_{\sigma}N$ , or  $a.ma \rightarrow a.bma$ ), the language must also license shielding in the tautosyllabic anticipatory context ( $VN]_{\sigma}$ , or  $am \rightarrow abm$ ). In Chapter 3, we also saw that if a language neutralizes contrasts in vocalic nasality preceding an onset nasal, it must also neutralize contrasts in vocalic nasality preceding a coda nasal. And finally, in Chapter 4, we saw that if a language prohibits a nasal-stop sequence from being followed by an onset nasal consonant ( $*NC_1VN_2V$ ), it also prohibits a nasal-stop sequence from being followed by another nasal-stop sequence ( $*NC_1VNC_2$ ) (with one exception, discussed in Chapter 4). These three generalizations appear, on the surface, completely unrelated – they hold in different empirical domains, over different sets of languages. But as shown in Chapters 3 and 4, these generalizations ultimately stem from the same phonetic asymmetry, namely an asymmetry in the amount of anticipatory nasalization induced by coda vs. onset nasals.

More broadly, it is worth noting that all generalizations established in this study can be predicted with reference to constraints that reference the presence vs. absence of five auditory properties, which together cue three contrasts: for N–NC,  $\Delta$  *burst* and  $\Delta$  *formant quality (following segment)*; for C–NC,  $\Delta$  *nasal consonant formants* and  $\Delta$  *formant quality (preceding segment)*; and for V– $\tilde{V}$ ,  $\Delta$  *nasal formant duration*. The theory of NC distribution advanced here is thus fairly simple (as it requires reference to fairly few constraints), but has substantial empirical coverage.

Regarding the specificity of predictions: throughout the study, we have seen that the contrast-based account is capable of making a number of specific and accurate predictions about the distribution of NCs. In Chapter 4, for example, we saw that the contrast-based analysis correctly predicts that the degree to which a language tolerates  $NC_1VNC_2$  can depend on the salience of  $NC_1$ 's oral release. In that same chapter, we saw that the analysis correctly predicts that  $NC\tilde{V}$  sequences should be cross-linguistically better-tolerated when the nasal vowel is long. More generally, we have seen in this study that all stated predictions of the contrast-based account – no matter how specific they are, or what aspect of the distribution of NCs they address – are borne out. The strength of the contrast-based account, then, is its ability to predict all of the generalizations detailed in this study, based on a fairly small set of phonetic generalizations and their perceptual consequences.

Equally important and revealing evidence for the contrast-based approach comes from links between generalizations established in Chapters 2 and 3, where it is shown that the distribution of neutralizing phenomena precisely parallels the distribution of enhancement phenomena. Under a contrast-based account, neutralization and enhancement are two repairs to the same problem: both exist to avoid insufficiently distinct contrasts. Thus if neutralization or enhancement targets some contrast  $x$ – $y$  in a context where cues to the contrast are maximally available, neutralization or enhancement should also target  $x$ – $y$  in all contexts where cues to the contrast are comparatively reduced (see also Flemming 2008a on the relationship between neutralization and enhancement). The behavior of nasal-stop sequences shows that this prediction is the correct one, and is the first strong evidence of its kind. Under any analysis that does not reference contrast, the source of the observed link between the distributions of neutralization and enhancement phenomena is mysterious.

At this point, we can return to the larger question behind this thesis: do constraints on contrast distinctiveness belong in CON? If it is correct to say that the distribution of NCs are constraints on contrast, and that there is no plausible alternative available (as argued at various points throughout Chapters 2–4), then the answer to this larger question is necessarily yes.

\*\*\*

The preceding chapters have introduced a substantial number of implicational generalizations. In Section 5.1 I provide a summary of these generalizations, annotated with the number of exceptions (apparent or otherwise, see the cited sections for details) and a reference to the section in which they are established. For each generalization, I have also provided a brief explanation as to why it is predicted by the a contrast-based account developed here; for further details and references, about both the generalization and the explanation, see the cited section(s). All generalizations summarized below are original to this study, unless indicated otherwise. In section 5.2, I indicate some directions for further research, and section 5.3 concludes.

## 5.1 Summary of empirical generalizations

- (1) **If a language licenses any N–NC contrast word-finally, it also licenses that N–NC contrast prevocally.** (Chapter 2.2.1, 0 exceptions)

*Explanation:* N–NC contrasts are more distinct in prevocalic position than they are in word-final position, due to the availability of a following vowel (Chapter 2.1.2). If a language licenses N–NC where it is less distinct, it will also license N–NC where it is more distinct.

- (2) **If a language licenses any C–NC contrast word-initially, it also licenses that C–NC contrast postvocally.** (Chapter 2.3.1, 2 exceptions)

*Explanation:* C–NC contrasts are more distinct in postvocalic position than they are in word-initial position, due to the availability of a preceding vowel (Chapter 2.1.2). If a language licenses C–NC where it is less distinct, it will also license C–NC where it is more distinct.

- (3) **If a language displays post-nasal devoicing prevocally, it will also display post-nasal devoicing word-finally.** (Chapter 2.2.5, 0 exceptions)

*Explanation:* Since  $N-NT$  contrasts are more distinct than  $N-ND$  contrasts (Chapter 2.1.2), post-nasal devoicing can be viewed as enhancement of an  $N-ND$  contrast. If enhancement targets the  $N-ND$  contrast where it is more distinct (prevocally), enhancement should also target the  $N-ND$  contrast where it is less distinct (word-finally).

- (4) **All languages that exhibit environmental shielding independently license a contrast in vocalic nasality (also Herbert 1986, following Haudricourt 1970).** (Chapter 3.1.1, 3 exceptions)

*Explanation:* Environmental shielding occurs to render contrasts in vocalic nasality maximally distinct. If a language does not license a contrast in vocalic nasality, then there is no reason for environmental shielding to occur.

- (5) **If a language exhibits shielding in the heterosyllabic anticipatory context, it also exhibits shielding in the perseveratory context (if  $V]_{\sigma}N \rightarrow V]_{\sigma}DN$ , then  $NV \rightarrow NDV$ ).** (Chapter 3.2.2, 0 exceptions)

*Explanation:* Oral vowels become more nasalized in the perseveratory context than they do in the heterosyllabic anticipatory context (Chapter 3.2.1). Assuming that the more nasal coarticulation in an oral vowel, the less distinct it becomes from a nasal vowel: if shielding occurs to protect  $V-\tilde{V}$  where it is more distinct (in the heterosyllabic anticipatory context) it will occur to protect  $V-\tilde{V}$  where it is less so (in the perseveratory context).

- (6) **If a language exhibits shielding in the heterosyllabic anticipatory context, it also exhibits shielding in the tautosyllabic anticipatory context (if  $V]_{\sigma}N \rightarrow V]_{\sigma}DN$ , then  $VN]_{\sigma} \rightarrow VDN]_{\sigma}$ ).** (Chapter 3.2.2, 0 exceptions)

*Explanation:* Oral vowels become more nasalized in the tautosyllabic anticipatory context than they do in the heterosyllabic anticipatory context (Chapter 3.2.1). Assuming that the more nasal coarticulation in an oral vowel, the less distinct it becomes from a nasal vowel: if shielding occurs to protect  $V-\tilde{V}$  where it is more distinct (in the heterosyllabic anticipatory context) it will occur to protect  $V-\tilde{V}$  where it is less so (in the tautosyllabic anticipatory context).

- (7) **If a language allows a  $V-\tilde{V}$  contrast (where the vowels are short), it also allows a  $V:-\tilde{V}$  contrast (where the vowels are long).** (Chapter 3.2.3, 0 exceptions)

*Explanation:* The longer the duration of acoustic nasality in a given vowel, the more likely it is that that vowel will be perceived as nasal (Chapter 3.2.3). If a language permits a contrast in vocalic nasality among short vowels (where nasal and oral vowels are likely less distinct), it should also permit a contrast in vocalic nasality among long vowels (where nasal and oral vowels are more distinct).

- (8) **If a language neutralizes the  $V-\tilde{V}$  contrast in the heterosyllabic anticipatory context, it also neutralizes the  $V-\tilde{V}$  contrast in the perseveratory context.** (Chapter 3.3, 2 exceptions)

*Explanation:* Oral vowels become more nasalized in the perseveratory context than they do in the heterosyllabic anticipatory context (Chapter 3.2.1). Assuming that the more nasal

*coarticulation in an oral vowel, the less distinct it becomes from a nasal vowel: if neutralization targets  $V-\tilde{V}$  where it is more distinct (in the heterosyllabic anticipatory context) it will target  $V-\tilde{V}$  where it is less so (in the perseveratory context).*

- (9) **If a language neutralizes the  $V-\tilde{V}$  contrast preceding onset nasals, it also neutralizes the  $V-\tilde{V}$  contrast preceding coda nasals.** (Chapter 3.3, 0 exceptions)

*Explanation: Oral vowels become more nasalized in the tautosyllabic anticipatory context than they do in the heterosyllabic anticipatory context. Assuming that the more nasal coarticulation in an oral vowel, the less distinct it becomes from a nasal vowel: if neutralization targets  $V-\tilde{V}$  where it is more distinct (in the heterosyllabic anticipatory context) it will target  $V-\tilde{V}$  where it is less so (in the tautosyllabic anticipatory context).*

- (10) **If a language bans  $NC_1V]_\sigma N_2$ , it will also ban  $NC_1VN_2]_\sigma$**  (also Herbert 1977, 1986). (Chapter 4.3.1, 1 exception)

*Explanation: Coda nasals induce more coarticulatory nasalization than do onset nasals (Chapter 3.2.1, 4.3.1). If a language bans  $N-NC$  when the preceding vowel is less nasalized (and  $N-NC$  is more distinct), it will also ban  $N-NC$  when the preceding vowel is more nasalized (and  $N-NC$  is less distinct).*

- (11) **If a language bans  $NC_1VND_2$ , it also bans  $NC_1VNT_2$ .** (Chapter 4.3.1, 0 exceptions)

*Explanation: Nasals that precede voiceless stops induce more coarticulatory nasalization than do nasals that precede voiced stops (Chapter 4.3.1). If a language bans  $N-NC$  when the preceding vowel is less nasalized (and  $N-NC$  is more distinct), it will also ban  $N-NC$  when the preceding vowel is more nasalized (and  $N-NC$  is less distinct).*

- (12) **If a language bans  $ND_1VN_2\dots$ , it will also ban  $NT_1VN_2\dots$**  (see also Herbert 1977, 1986). (Chapter 4.3.2, 0 exceptions)

*Explanation:  $N-NT$  contrasts are more distinct than  $N-ND$  contrasts, as they display more robust internal cues: longer oral component, more salient release, etc. (Chapter 2.1.2, 4.3.2). If a language bans  $N-NT$  (where internal cues are more robust) from contexts where external cues to the contrast are compromised, it should ban  $N-ND$  (where internal cues are less robust) from that same context.*

- (13) **If a language bans  $NC_1VNC_2$  when  $NC_1$  is heterorganic, it also bans  $NC_1VNC_2$  where  $NC_1$  is homorganic.** (Chapter 4.3.3, 0 exceptions)

*Explanation: Heterorganic  $N-NC$  contrasts may be more distinct than homorganic  $N-NC$  contrasts, assuming that a longer oral component means a more salient release (Chapter 4.3.3). If a language bans heterorganic  $NC$  (where internal cues are more robust) from contexts where external cues to the contrast are compromised, it should ban homorganic  $NC$  (where internal cues are less robust) from that same context.*

- (14) **If a language bans  $NC_1V:NC_2$  (where the vowel is long), it will also ban  $NC_1VNC_2$  (where the vowel is short).** (Chapter 4.3.4, 0 exceptions)

*Explanation:* Assuming that the duration of coarticulatory nasalization induced onto a given vowel is independent of the length of that vowel, we would expect the short vowel in  $NC_1VNC_2$  to be comparatively more nasalized than the long vowel in  $NC_1V:NC_2$ . Languages that ban  $NC_1V:NC_2$ , where the intermediate vowel is less nasalized (and  $N-NC_1$  is more distinct) should also ban  $NC_1VNC_2$ , where the intermediate vowel is more nasalized (and  $N-NC_1$  is less distinct).

- (15) **If a language bans  $NC_1\dots NC_2$  (resulting in apparently non-local nasal cluster effects), it also bans  $NC_1VNC_2$  (resulting in local nasal cluster effects).** (Chapter 4.4, 0 exceptions)

*Explanation:* Bans on  $NC_1VNC_2$  are driven by the existence of coarticulatory nasalization in the intervening vowel, which reduces cues to the  $N-NC_1$  contrast (Chapter 4.2.1, 2.1.2). If nasalization is capable of spreading from  $N_2$  through an unlimited amount of intervening material, it should be capable of spreading through a single vowel.

- (16) **If a language allows  $NC\tilde{V}$ , it should also allow  $NC_1VN_2\dots$**  (Chapter 4.6.1, 0 exceptions)

*Explanation:* Phonemically nasal vowels are more nasal than allophonically nasalized vowels (Chapter 4.6). If  $NC$  is permitted before a phonemically nasal vowel (where it is likely less distinct from  $N$ ), it should be permitted before an allophonically nasalized vowel (where it is likely more distinct from  $N$ ).

- (17) **If a language bans  $NC_1VN_2\dots$ , it should also ban  $NC\tilde{V}$ .** (Chapter 4.6.2, 0 exceptions)

*Explanation:* Phonemically nasal vowels are more nasal than allophonically nasalized vowels (Chapter 4.6). If  $NC$  is banned before an allophonically nasalized vowel (where it is likely more distinct from  $N$ ), it should be banned before a phonemically nasal vowel (where it is likely less distinct from  $N$ ).

- (18) **If a language allows  $NC\tilde{V}$ , it also allows  $NCV$ .** (Chapter 4.6.1, 0 exceptions)

*Explanation:* In  $NC\tilde{V}$  sequences, the presence of a nasal vowel renders  $NC$  confusable with  $N$  (Chapter 2.1.2). If  $NC$  is allowed to surface before a nasal vowel (where it is less distinct from  $N$ ), it should also be allowed to surface before an oral vowel (where it is more distinct from  $N$ ).

- (19) **If a language allows  $NC\tilde{V}$  (where the vowel is short), it will also allow  $NC\tilde{V}:$  (where the vowel is long).** (Chapter 4.7.2, 0 exceptions)

*Explanation:* Long nasal vowels are more distinct from oral vowels than are short nasal vowels (Chapter 3.2.3). If a language permits  $NC\tilde{V}$  sequences (where the  $V-\tilde{V}$  contrast is more compromised by the perseveratory oral transitions from  $NC$ ), it should permit  $NC\tilde{V}:$  sequences (where the  $V-\tilde{V}$  contrast is less compromised by the perseveratory oral transitions from  $NC$ ).

## 5.2 Directions for future work

In this section, I outline three avenues for future work, both of which would enable us to expand and further test the predictions of the contrast-based account. Section 5.2.1 outlines potential connections among the phenomena discussed in this study, focusing on the predictions the theory makes regarding languages that exhibit more than one of the phenomena under consideration here. Section 5.2.2 describes an additional type of nasal-stop sequence – those that appear as allophonic variants of *voiced stops* – that has not been discussed thus far in the study. Finally, section 5.2.3 discusses some potential implications of this work for the structure of MINDIST constraints.

### 5.2.1 Connections among phenomena

In this subsection, I discuss three kinds of potential languages: those that exhibit both shielding and contrastive prenasalization; those that exhibit restrictions on both NC $\tilde{V}$  as well as word-final NCs; and those that exhibit both shielding and a restriction on NC<sub>1</sub>VNC<sub>2</sub>. In these three cases, the current theory makes testable predictions about whether or not and/or how these phenomena should interact with one another, within a single system. What we find, however, is that the number of systems that allow us to test these predictions is small, and that in most cases it is at present unclear whether or not the predictions hold as stated. Additional survey work is necessary for further investigation.

#### Shielding and prenasalization

In Chapter 2, we considered a number of languages in which NC sequences contrast with their component parts, Ns and Cs; in Chapter 3, we considered a number of languages in which NC sequences vary allophonically with Ns as a function of the quality of the following vowel. Thus we might imagine that there exist languages that exhibit both phenomena, and we might wonder what the analysis of such languages would look like.

To get a sense of what a language that exhibits both contrastive prenasalization and shielding would look like, consider the following system (Wari''), a variant on the pattern attested in Wari' (Everett & Kern 1997). In stressed syllables, a contrast in vowel nasality is licensed, and [m] and [mb] vary allophonically according to the quality of the following vowel (20a). But in stressless syllables, the contrast in vowel nasality is neutralized, and [m] and [mb] contrast (20b). This system is thus one in which both N–NC and V– $\tilde{V}$  contrasts are licensed, but only in contexts where the other is not.

- (20) Distribution of N–NC and V– $\tilde{V}$  in Wari''
- a. In stressed syllables, V– $\tilde{V}$  is licensed, but N–NC is not.
    - (i) V– $\tilde{V}$  licensed: ✓'ta, ✓'tã
    - (ii) N–NC neutralized: ✓'mã, ✓'mba; but \*'ma, \*'mbã
  - b. In stressless syllables, N–NC is licensed, but V– $\tilde{V}$  is not.
    - (i) V– $\tilde{V}$  neutralized: ✓a'ta, but \*ã'ta
    - (ii) N–NC licensed: ✓ma'ta, ✓mba'ta

Such systems, however, do not exist in the typology of shielding languages considered for this paper: languages that have contrastive prenasalization do not have prevocalic shielding, and languages that have prevocalic shielding do not have contrastive prenasalization.<sup>1</sup> This gap, if it is meaningful,

<sup>1</sup>There is one language, Apinayé (Oliveira 2005) that has contrastive prenasalization and *postvocalic* shielding; see the Apinayé notes in section 3.6.2.



would be surprising: there is no component of the present theory that predicts that a language should only license shielding if it does not allow an N–NC contrast, or that a language should only allow an N–NC contrast if it does not license shielding.

But given the data currently available to us, there is a distinct possibility that the absence of languages that lack the combination of prevocalic shielding and an N–NC contrast is due to chance, i.e. that the gap is not theoretically meaningful. Of the 324 South American languages surveyed in Chapter 3, 62 exhibit prevocalic shielding, and only 7 exhibit contrastive prenasalization (21).<sup>2</sup>

(21) Distribution of contrastive prenasalization in shielding vs. non-shielding languages

	Contrastive prenasalization	No contrastive prenasalization
Prevocalic shielding	0	62
No prevocalic shielding	7	255

Taking into account the rarity of contrastive prenasalization in the sample, and the relative rarity of prevocalic shielding, it is possible that the lack of languages exhibiting both shielding and contrastive prenasalization is due to chance; there is no significant correlation between the frequency of contrastive prenasalization and the existence of prevocalic shielding (Fisher’s Exact test,  $p = .35$ ).

Thus while the current theory predicts that we should find languages that license both shielding and contrastive prenasalization, no languages exhibiting both properties has yet been identified. Further work and a larger sample size is necessary to determine if this gap is meaningful, i.e. something that needs to be accounted for by a successful theory of the distribution of NCs.

### Languages with restrictions on NC $\tilde{V}$ and NC#

In Chapter 2, we saw that there are a number of languages that ban NCs from occurring in word-final position. In Chapter 4, we saw that there are a number of languages that ban NCs from occurring when they directly precede a nasal vowel. If we assume that NCs are equally or less distinct from Ns when they precede a word boundary than they are when they precede a nasal vowel ( $\Delta$  N–NC /  $\_ \tilde{V}$  >  $\Delta$  N–NC /  $\_ \#$ ), then the contrast-based analysis predicts an implicational generalizations regarding the licensing of these two structures: if a language allows a word-final contrast between N and NC, it must also allow NC $\tilde{V}$  sequences to surface. This is because, if a language licenses a word-final N–NC contrast, it does so in the absence of  $\Delta$  *CV transitions*; therefore it should license N–NC regardless of the quality of the following vowel.

Is this prediction correct? From the available data, the answer is unclear: of the languages that license N–NC and V– $\tilde{V}$ , only one (Páez) appears to allow N–NC contrasts in word-final position. Páez is classified as a ‘permissive’ language in Chapter 2 (i.e. it allows both prevocalic and word-final contrasts), but the status of final N–NC contrasts is somewhat more complicated than was revealed at that point. According to Rojas Curieux’s (1997) description, final N–NC contrasts can be realized faithfully (e.g. [s<sup>y</sup>a<sup>m</sup>b] ‘pueblo’); they can be enhanced through devoicing and aspiration (e.g. [s<sup>y</sup>a<sup>m</sup>p<sup>h</sup>] ‘pueblo’), or they can be neutralized (e.g. s<sup>y</sup>a<sup>m</sup>b<sub>o</sub>] ‘pueblo’) (all data from Rojas Curieux 1998: 94). There is no information provided as to the relative frequency of these variants, or if there are any conditioning factors (e.g. style, speech rate, or sociolinguistic factors), and Jung’s (2008: 34) description of the same phenomenon presents a slightly different picture, in which NCs are categorically devoiced word-finally.

<sup>2</sup>Whether or not a language exhibits contrastive prenasalization was determined by consulting the phonemic inventory provided by SAPHon (Michael et al. 2012), and cross-checking that inventory with the original source. This second step was necessary because in many cases the inventory provided by SAPHon lists both Ns and NCs as independent phonemes, when in fact they are in complementary distribution.

It doesn't seem unreasonable, then, to say that Páez is a language in which word-final N–NC contrasts must be enhanced to be sufficiently distinct. The question, then, is why these contrasts are neutralized before nasal vowels, and not enhanced – why do we not see ND devoicing in contexts where the NC precedes a nasal vowel? Words in which a nasal vowel follows a voiceless stop are licit (e.g. [t<sup>h</sup>ũa] ‘ear’, Rojas Curieux 1998: 92, translation mine), as are words in which a voiceless stop occurs intervocalically (e.g. [ut<sup>y</sup>a] ‘ear’, Rojas Curieux 1998: 90, translation mine); the failure of N–NC enhancement to occur preceding nasal vowels does not appear to be due to any obvious restriction on TṼ sequences, at any position in the word.

The prediction that licensing of word-final N–NC should imply licensing of NCṼ, then, appears to be unsupported. But before rejecting the current theory on this basis, it seems prudent to construct a larger typology containing more languages that license both word-final N–NC as well as a V–Ṽ contrast, in order to establish that there is in fact no correlation between licensing of final N–NC and licensing of NCṼ (i.e. that Páez is not an outlier in this respect). And it would also be necessary to establish, through a perceptual experiment, that it is in fact the case that we expect this asymmetry to hold: that NCs are in fact less distinct from Ns when they precede a word boundary than they are when they precede a nasal vowel ( $\Delta$  N–NC / \_Ṽ >  $\Delta$  N–NC / \_#). To date, this has not been tested.

### **Languages with shielding and restrictions on NC<sub>1</sub>VNC<sub>2</sub>**

Recall, from Chapter 4, that the current analysis of the cross-linguistic dispreference for NC<sub>1</sub>VNC<sub>2</sub> relies crucially on cues to the N–NC contrast: NC<sub>1</sub>VNC<sub>2</sub> is dispreferred as nasalization on the intervening vowel, stemming from the nasal portion of NC<sub>2</sub>, renders NC<sub>1</sub> insufficiently distinct from a plain nasal. We would thus expect to find a dispreference for NC<sub>1</sub>VNC<sub>2</sub> *only* in languages that license an N–NC contrast; in other words, in languages where NCs vary allophonically with Ns, we do not expect to see similar effects.

Is this prediction correct? An investigation of the shielding typology, i.e. of a set of 66 languages where N varies allophonically with NC, suggests that the answer is *mostly*. The only language that appears to exhibit both shielding and restrictions on NC<sub>1</sub>VNC<sub>2</sub> is Aguaruna, where Overall (2007: 52) writes that “the nasal consonants /m, n/ are partially or fully denasalized in non-nasal environments, that is following a sequence of contiguous oral vowels and sonorants that is not followed by a nasal consonant.” Although this is not stated explicitly, the implication is that while words like [bifu]~[<sup>m</sup>bifu] ‘cat’ and [i<sup>n</sup>dauk] ‘camote (sweet potato)’ are licit (both Overall p. 53), a hypothetical form like [<sup>m</sup>ba<sup>n</sup>da] would not be.

There is potentially an outside factor contributing to Aguaruna’s apparent exceptionality: it also exhibits nasal harmony (see esp. Overall 2007: 50–51). Spreading in Aguaruna is bidirectional, triggered by nasal vowels, and holds across contiguous vowels and glides that reside within the same phonological word. Thus it might be possible to explain the apparent ban on NC<sub>1</sub>VNC<sub>2</sub> sequences as a consequence of nasal harmony: the reason why [<sup>m</sup>bi<sup>n</sup>di] is not a possible word is because the intermediate [i], perhaps nasalized by the following nasal consonant, must agree for [+nasal] with the consonant that precedes it (so \*[<sup>m</sup>bi<sup>n</sup>di], but ✓[mi<sup>n</sup>di]). This said, however, there are questions regarding how this analysis would work – is it really the case that allophonically nasalized vowels trigger harmony (as in Capanahua; Safir 1979)? If so, and if harmony is bidirectional, why is it the case that words like [mi<sup>n</sup>di] can exist at all? Why does the nasalization present on the intermediate [i] not spread, progressively, to the word’s final segments (resulting in [mĩni])?

In short, the prediction that we should only find nasal cluster effects (\*NC<sub>1</sub>VNC<sub>2</sub>) in languages where NCs contrast with their component parts appears to be, for the most part, upheld. While I

believe that there is likely a plausible explanation for why Aguaruna is an apparent exception, the details remain to be worked out.

### 5.2.2 Uninvestigated phenomena

The discussion in Chapter 3 focuses on one kind of allophonic nasal-stop sequence: those that occur as allophonic variants of nasal consonants, depending on the quality of the surrounding vowels. But the discussion in that chapter was not comprehensive, as nasal-stop sequences can occur as allophones of other kinds of phonemes as well. We will focus here on the appearance of nasal-stop sequences as allophones of *voiced stops*, in systems that license a voicing contrast.

One language in which NCs appear as allophones of voiced stops is Minica Huitoto (Minor & Minor 1976). In this language, there are three series of stops: voiced and voiceless oral, as well as nasal. Minimal pairs are in (22); translations from the original Spanish are mine.

- (22) Stop contrasts in Minica Huitoto (Minor & Minor 1976: 61–62)
- a. *Voiced vs. voiceless*  
čupíde ‘to chip’ vs. tubíde ‘hit the water to make noise’
  - b. *Voiced vs. nasal*  
óogodo ‘banana’ vs. óoŋodo ‘toad (instrumental case)’

The phonetic realization of voiced stops, however, depends on their position: voiced stops in intervocalic position are realized as plain voiced stops, but voiced stops in word-initial position are prenasalized (23).

- (23) Voiced stop realization in Minica Huitoto (Minor & Minor 1976: 63)
- a. *Voiced stops are voiced intervocalically*  
see exx. in (22)
  - b. *Voiced stops are prenasalized word-initially*  
[<sup>m</sup>béja] ‘corn’, [<sup>ɲ</sup>gúku] ‘a type of toad’

Why would voiced stops be prenasalized in word-initial position? One possibility is that prenasalization serves, in this context, to *enhance voicing contrasts*. As noted by Herbert (1986), Flemming (2004), and others, contrasts between voiced NCs and voiceless stops are likely more distinct than are contrasts between plain voiced and voiceless stops ( $\Delta$  [nd–t] >  $\Delta$  [d–t]), as prenasalized stops are more strongly voiced than are plain voiced stops (see Flemming 2004: 258ff for discussion and references to phonetic work; also Chapter 1.2.2).

If it is in fact the case that prenasalization of voiced stops serves to enhance contrasts for [ $\pm$ voice], then we would expect the following generalization to hold: if prenasalization targets a *more* distinct [ $\pm$ voice] contrast, it should also target all *less* distinct [ $\pm$ voice] contrasts. Furthermore, we would expect that, all else equal, the distribution of allophonic prenasalization should directly parallel the distribution of [ $\pm$ voice] neutralization. This is because, as discussed in Chapter 3, a contrast-based analysis treats enhancement and neutralization as two possible solutions to the same problem: thus any neutralization or enhancement phenomenon that targets some contrast  $x$ – $y$  in some context  $C_1$  must also target  $x$ – $y$  in all contexts  $C_2$  where  $x$ – $y$  is less distinct.

The typology of [ $\pm$ voice] neutralization has been worked out in some detail by Steriade (1997), and is summarized below. Contexts towards the left of the table are less well-cued; contrasts towards the right of the table are better-cued (see Steriade 1997: 5–8 on cues to voicing). Following Steriade, I use ‘O’ to denote an obstruent and ‘R’ to denote a sonorant. The presence of a voicing contrast is

indicated with a checkmark (✓); if the contrast is neutralized, that is indicated with an asterisk (\*); if the status of the contrast cannot be determined (i.e. the sequence is missing), this is marked with a dash (–). The examples cited here are the same as those cited by Steriade (1997: 9).

(24) Summary of [±voice] neutralization (Steriade 1997)

Context					Example
#_O, O_#	R_O	R_#	_R	R_R	
bsa vs. psa	absa vs. apsa	ab vs. ap	ba vs. pa	aba vs. apa	
*	*	*	*	✓	Totontepec Mixe (Crawford 1963)
*	*	*	✓	✓	Lithuanian (Senn 1966)
*	*	✓	✓	✓	French (Dell 1995)
*	✓	✓	✓	✓	Shilha (Applegate 1958)
✓	–	✓	✓	✓	Khasi (Nagaraja 1985)

Does the distribution of allophonic prenasalization display these same contextual asymmetries? The fact that Minica Huitoto displays allophonic prenasalization in word-initial position only is consistent with the prediction that it should: word-initial voicing contrasts are less well-cued than are intervocalic voicing contrasts, meaning that if we find enhancement in only one of these contexts, it should be in word-initial position.<sup>3</sup> But whether or not the larger typology of allophonic prenasalization follows these implicational laws has not, to the best of my knowledge, been investigated in any systematic way. Further work on this question stands to contribute to our knowledge both as it regards the distribution of nasal-stop sequences, and as it regards the relationship between enhancement and neutralization phenomena.

### 5.2.3 On the structure of MINDIST constraints

It has been demonstrated throughout this thesis that a grammar equipped with MINDIST constraints is capable of making a set of strong and accurate predictions regarding the distribution of NCs. There have been several points in the discussion, however, where it has become clear that restrictions on the relevant contrasts do not always impact the distribution of NCs. I summarize these points below and speculate briefly on what they have the potential to teach us regarding the composition of possible MINDIST constraints and the structure of the grammar more generally.

#### Shielding is not sensitive to contrastive status of individual Vs

In Chapter 3, we saw that many of the laws that govern the typology of shielding in South American languages can be predicted by reference to constraints on contrast. For example, the fact that shielding occurs only in languages that license a V– $\tilde{V}$  contrast can be explained if shielding is a form of contrast enhancement, and as such, shielding would serve no function in languages that do not license a contrast in vocalic nasality. In addition, the fact that shielding in the tautosyllabic anticipatory context (VN] <sub>$\sigma$</sub> ) implies shielding in the heterosyllabic anticipatory context (V] <sub>$\sigma$</sub> N) can be explained under the assumption that shielding, as a form of enhancement, must first target contrasts in vocalic nasality that are relatively less distinct – an oral vowel in the tautosyllabic anticipatory context is likely to be more heavily nasalized, and thus less distinct from a nasal vowel.

But we also saw that there are several ways in which shielding does *not* track generalizations regarding the licensing of V– $\tilde{V}$  contrasts, in ways that we might expect it to, were MINDIST con-

<sup>3</sup>Minica Huitoto allows only V and CV syllables (Minor & Minor 1976: 65), so whether or not allophonic prenasalization would target any of the other contexts listed in (24) cannot be determined.

straints able to refer to finer details regarding the distribution of contrasts they aim to enhance. In 26 of the 66 shielding languages included in the survey, the inventory of oral vowels is larger than the inventory of nasal vowels; in Hup (Epps 2008), for example, the high and low vowels contrast for nasality ([i-ĩ], [i-ĩ̃], [u-ũ], [æ-æ̃], [a-ã], [ɔ-ɔ̃]), but the mid vowels do not ([e], [ə], and [o]; but \*[ẽ], \*[õ], \*[ō]). If shielding is a strategy to protect V- $\tilde{V}$  contrasts, then we might expect the distribution of shielding to track these restrictions on the inventory of nasal vowels: in Hup, for example, as [o] has no nasal counterpart, we might not expect a speaker to shield in that environment. What we find, though, is that restrictions on the distribution of shielding categorically do not track restrictions on the distribution of V- $\tilde{V}$  contrasts; more specifically, in languages where shielding occurs, it occurs adjacent to *all* oral vowels – not just those that contrast with a nasal vowel of the same quality. (In Hup, for example, shielding occurs adjacent to [o], e.g. [tôd<sup>n</sup>] ‘hollow log’, Epps 2008:55.)

A second generalization along these lines worth mentioning here has to do with contextual restrictions on the distribution of V- $\tilde{V}$  contrasts. In some languages, contrasts in vocalic nasality are licensed only in certain environments; in Wari’, for example, all V- $\tilde{V}$  contrasts are mainly limited to the stressed syllable. If a V- $\tilde{V}$  contrast is limited to a certain position within the word, we might imagine that shielding should track this restriction. In Wari’, for example, there is no motivation to shield in stressless syllables, as there is no V- $\tilde{V}$  contrast in this environment. On the basis of five languages, Chapter 3.5.1 claims that this prediction is correct. That said, however, it is often hard to discern from the available descriptions exactly what are the contextual restrictions on the distribution of shielding and on the V- $\tilde{V}$  contrast. To more firmly establish that this generalization holds, it is necessary to obtain and analyze a larger body of data for each surveyed language.

In short, there is ample support in Chapter 3 for the hypothesis that the constraints motivating shielding can “see” whether or not a language licenses a V- $\tilde{V}$  contrast. There is less support for the notion that these constraints are sensitive to restrictions on the distribution of V- $\tilde{V}$  contrasts, either at the level of the inventory or the level of the phonotactics, within the languages that license V- $\tilde{V}$ .

### **Restrictions on NC $\tilde{V}$ are not sensitive to contrastive status of NC**

The apparent lack of sensitivity on the part of MINDIST constraints to restrictions on the distribution of contrasts they refer to was replicated in Chapter 4, where we saw that the dispreference exhibited by many languages for NC $\tilde{V}$  sequences holds regardless of whether or not the NC in question is phonemically contrastive with a homorganic nasal. As discussed in Chapter 4, a survey of 23 languages that license N-NC and V- $\tilde{V}$  contrasts found that 11 of these ban NC $\tilde{V}$  sequences. Further analysis of six corpora revealed that three additional languages gradiently disprefer NC $\tilde{V}$  sequences (i.e., NC $\tilde{V}$  sequences are rarer in their lexica than we might expect, taking into account the independent frequencies of NCs and  $\tilde{V}$ s).

This result is perhaps surprising when we consider that in many of these languages, N-NC contrasts are distributionally restricted in some way. In Mbay, for example, bilabial and alveolar N-NC contrasts are licensed in all contexts ([m-mb], [n-nd]), but palatal and velar NCs have no plain nasal counterpart (so [ɲɲ] and [ŋŋ]; but \*[ɲ], \*[ŋ]). A further 6 of the 13 NC $\tilde{V}$ -dispreferring languages exhibit similar place-based restrictions on the N-NC contrast, yet restrictions on NC $\tilde{V}$  licensing do not track these more detailed restrictions at all. In other words, while we might expect NC $\tilde{V}$  sequences to be allowed when NC does not contrast with a homorganic N, in no language does such a pattern arise. A similar observation comes from Ngbaka, where the velar N-NC contrast is neutralized to NC in initial position (so [aŋga-aŋa] in medial position, but only [ŋga] word-

initially).<sup>4</sup> But the distinctiveness constraints that drive the dispreference for NC $\tilde{V}$  appear not to be sensitive to this restriction on the distribution of [ŋ–ŋg], as [ŋg $\tilde{V}$ ] appears to be dispreferred in initial position just as much as it is in word-medial position (see Chapter 4.11.2 for the statistical analysis).

## Discussion

In short, then, evidence from Chapters 3 and 4 suggests the following. While MINDIST constraints are sensitive to the existence of a contrast for some feature [F] in a language’s phonemic inventory (e.g. the contrast between oral and nasal vowels, or the contrast between Ns and NCs), they are less sensitive – or perhaps not sensitive at all – to restrictions on the distribution of the contrast for [F], at the level of the inventory or at the level of the phonotactics.

Whether or not the asymmetry outlined above holds more broadly, in more empirical domains, remains to be seen. But to the extent that restrictions on the granularity of reference to contrast is a consistent theme throughout this study, it suggests that there are restrictions on the types and combinations of properties that MINDIST constraints can refer to. For example: it cannot be the case that distinctiveness constraints on the V– $\tilde{V}$  contrast refer to vowel quality as well, as we have seen that enhancement phenomena targeting the V– $\tilde{V}$  contrast are not sensitive to whether or not a particular oral vowel contrasts with a nasal vowel of that same quality. These kinds of restrictions could potentially be encoded as restrictions on the combinations of properties that MINDIST constraints are capable of referring to – though I am not yet ready to offer a concrete proposal along those lines. In any case, the findings here strongly suggest that an assumption running through most of the work on constraints on contrast – that distinctiveness constraints evaluate only minimally distinct inputs, i.e. those that differ only in the property of interest (e.g. Flemming 2008b: 18) – should be weakened or abandoned entirely.

## 5.3 Conclusion

Based on the empirical generalizations outlined in Section 5.1, this study has claimed that the correct theory of the distribution of nasal-stop sequences must incorporate constraints on contrast. More broadly, the study provides a number of arguments in support of the hypothesis that constraints on contrast distinctiveness are part of CON. It also stands to contribute to our knowledge of what kinds of MINDIST constraints belong in CON, as several of the generalizations that govern the distribution of NCs hint at possible restrictions on the combinations of properties they are able to refer to (see Section 5.2.3 for discussion). The hope is that further investigation of the questions outlined in Section 5.2 will serve to strengthen the conclusion that constraints on contrast are part of CON, and to help us understand exactly what are the restrictions on the form of these constraints.

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<sup>4</sup>In Gbaya Kara, a similar restriction holds: intervocalically, labiovelar NCs do not contrast with Ns.

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