Environmental shielding is contrast preservation*

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ABSTRACT. The term *environmental shielding* refers to a class of processes in which the phonetic realization of a nasal stop depends on its vocalic context. In Chiriguano (Tupí; Dietrich 1986), for example, nasal consonants are realized as such before nasal vowels (/mã/ → [mã]), but acquire an an oral release before oral vowels (/ma/ → [mba]). Herbert (1986) claims that shielding protects a contrast between oral and nasal vowels: if Chiriguano /ma/ were realized as [ma], [a] would likely carry some degree of nasal coarticulation, and be less distinct from nasal /ã/. This article provides new arguments for Herbert's position, drawn from a large typological study of South American languages. I argue that environmental shielding is contrast preservation, and that any successful analysis of shielding must make explicit reference to contrast. These results contribute to a growing body of evidence that constraints on contrast are an essential component of phonological theory.

1 Introduction

The hypothesis that constraints on contrast are a necessary component of the phonological grammar (Flemming 2002) has received a significant amount of support. Recent work has argued that appealing to constraints on contrast leads to desirable results, including: the ability to accurately predict contextual restrictions on various segment types by taking into consideration the perceptibility of contrasts that they enter into, in different contexts (e.g. Steriade 1997, Flemming 2004); the potential to achieve a unified explanation of certain types of co-occurrence restrictions that otherwise appear contradictory (e.g. Gallagher 2010); and the potential to explain certain apparently opaque generalizations, e.g. vowel chain shifts in Finnish (Łubowicz 2012; see also Sanders 2003).

The present article contributes to this growing body of research by presenting a novel set of empirical arguments that constraints on contrast are an essential part of the speaker's phonological grammar. The arguments come from the typology of environmental shielding (hereafter just *shielding*), as established through a large-scale survey of South American languages (described in Section 2). In languages that exhibit shielding, the phonetic realization of a nasal consonant 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', p. 14), a nasal consonant acquires a brief oral phase at any position in which it is directly adjacent to an oral vowel (1).

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(1) Shielding in Karitiâna (Storto 1999:25-26)[1]

a. /m/ → [mb] / Ṽ_V, #_V (ex. /ã**m**o/ → [ã**mb**o] 'to climb')
b. /m/ → [bm] / V_#, V_Ṽ (ex. /ka**m**/ → [ka**bm**̚] 'now')
c. /m/ → [bmb] / V_V (ex. /api**m**ik/ → [api**bmb**ik̚] 'to pierce')
d. /m/ → [m] / *elsewhere* (ex. /ã**m**ãŋ/ → [ã**m**ãŋ̚] '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. When shielding occurs, then, the contrast between oral and nasal vowels is rendered maximally distinct.

The hypothesis that shielding preserves 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 *et seq.*), 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, then shielding should only be attested in languages that license a contrast in vocalic nasality. Section 2 presents 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; Section 3 shows that this prediction, too, is correct (to the extent that contextual asymmetries in the perceptibility of nasality can be indirectly quantified). Section 4 shows that the contrast-based analysis developed in this article makes correct predictions beyond the typology of shielding about the larger typology of vowel nasalization contrasts. In section 5 I discuss three potential alternative analyses that do not explicitly reference contrast, and show that they 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 contrasts in vocalic nasality. More broadly, contrast and the constraints that reference it are essential components of the phonological grammar.

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 2 is composed entirely of languages indigenous to South America; the smaller survey of 98 reported in Section 5 is composed mainly of languages whose grammars are on the shelves at MIT's Hayden Library and have call numbers in the PL5000–PM7875 range. The decision to restrict the survey in Section 2 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 5 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

[1]The exact allophones produced by shielding are to some extent speaker-dependent (see Storto 1999:20, Everett 2007).

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, this has yet to be verified.

2 The typology of shielding

This section addresses 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 2.1 presents the results of a large typological study suggesting that this prediction is correct, and discusses a couple of apparent counterexamples. Section 2.2 lays out what the successful criteria for an analysis of the typology are, and formalizes an analysis in Dispersion Theory (Flemming 2002 *et seq.*).

2.1 Survey methodology and results

The contrast-based approach to shielding sketched above makes a basic prediction: if shielding occurs to protect a contrast in vocalic nasality, shielding should 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) – where there is no contrast in vocalic nasality, but nasals are realized as (partially) oral consonants when adjacent to oral vowels – to exist.[2]

(2) Karitiâna′: shielding with no contrast in vocalic nasality

a. /m/ → [mb] / #_V	ex. /**m**a/ → [**mb**a]	(but *[**m**ã])
b. /m/ → [bm] / V_#	ex. /a**m**/ → [a**bm**]	(but *[ã**m**])
c. /m/ → [bmb] / V_V	ex. /a**m**a/ → [a**bmb**a]	(but *[ã**m**ã])

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 primarily determined by consulting the author's proposed inventory as well as any additional discussion regarding the role of vocalic nasality in the language's phonology. Of the 149 systems in which nasality was claimed to be lexically contrastive, for 81 I was able to

[2]Languages that lack nasals, e.g. Pawnee (Parks 1976), could be treated as cases where shielding applies in all contexts. But without any evidence to indicate 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; (ii) a contextual restriction on shielding, or (iii) the preservation of [+nasal] in some or all allophones that the shielding process produces (as in (2)).

verify this claim by locating minimal or near-minimal pairs. For 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]). For the remaining six systems, additional evidence of this sort was difficult to find, due to a lack of data provided in the description. For information on what kind of additional evidence was available for which language, see the Appendices.

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 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 and exhibits complementary distribution between nasal and oral stops according to the nasal vs. oral quality of the surrounding vowels (so [mã] and [ba], but *[ma] and *[bã]), there are two possible analyses. The first: the nasal stop is an allophone of the oral stop, conditioned by a following [+nasal] vowel (/b/ → [m] / _[+nasal]). The second: the oral stop is an allophone of the nasal stop, conditioned by a following [-nasal] vowel (/m/ → [b] / _[-nasal]). The interest of this article is in cases of the latter variety, where a nasal stop licenses an oral allophone when adjacent to an oral vowel. In languages where the nasal and oral allophones are in complementary distribution, however, it can be impossible to determine which of the above analyses is correct, as explicitly noted by some authors (e.g. Cathcart 1979:11 on Kakua).

The survey takes an inclusive approach towards what counts as 'shielding', providing as many chances as possible for the contrast-based hypothesis to be falsified. A language counts as 'having shielding', or exhibiting variation between a nasal and its oral allophone conditioned by a neighboring vowel, in all cases where this is a plausible interpretation of the data.[3] Thus languages like Kakua, where it is unclear if the alternations are due to shielding or to nasal harmony, 'have shielding'. By contrast, cases where it is more likely that the alternations are due to [+nasal] harmony – as is clear for Desano (Tucanoan, Silva 2012), for example, where [+nasal] harmony targets all segments except voiceless stops (e.g. /˜+pidu/ → [pĩɾ̃ũ] 'snake', /˜+dʉkʉ/ → [nʉ̃ʰkʉ̃] 'forest', Silva 2012: 74) – do not count as 'having shielding'. All 'shielding' languages for which there is a question of analysis are marked as such in Appendix B; all 'non-shielding' languages that display allophonic variation (due to [+nasal] harmony) are marked as such in Appendix C.

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 the generalizations drawn here. The prediction explored here is that *if a language displays shielding, it must license a contrast in vocalic nasality*. 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.

As shown in (3), with three potential exceptions, all languages with shielding license a contrast in vocalic nasality (a V-Ṽ contrast). For more information on the 66 languages that exhibit shielding and a V–Ṽ contrast, see Appendices A–B. For a list of the remaining 255, see Appendix C.

[3] 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.

(3)

	Shielding	No shielding
No V-Ṽ contrast	**3 lgs.** e.g. Umotína (Schultz 1952)	**172 lgs.** e.g. Shipibo (Elías-Ulloa 2010)
V-Ṽ contrast	**66 lgs.** e.g. Karitiâna (Storto 1999)	**83 lgs.** e.g. Urarina (Olawsky 2006)

As is clear from (3), the prediction of the contrast-based approach is largely borne out. In the following subsections I argue 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. For discussion of other apparent counterexamples that fall outside of the range of languages surveyed here, see Section 6.2.

2.1.1 Shielding in Umotína

Umotína, which does not license a contrast in vocalic nasality, exhibits variation between [m] and [b] in the form [ire**m**o'to] ∼ [ire**b**o'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 individual in question" (translation mine).[4]

Further discussion by Lima (p. 43) suggests it may be possible to predict the distribution of [m] and [b] by appealing to the [±syllabic] value of the following segment: [b] appears before [-syllabic] /w/ and /j/, and [m] appears before all vowels. If this is correct, there is an analysis available under which the [m∼b] variation is conditioned by syllabic position. Under this analysis, the [m–b] contrast is neutralized in all positions, with [m] as the default allomorph that appears before vowels (perhaps to maximize the contrast between it and the voiceless /p/). In onset consonant-glide clusters, however, /m/ is realized as [b], in order to maximize the cluster-internal sonority rise (see Zec 2007:188–189 on minimal sonority distance in clusters). As shielding is variation between voiced stops and their nasals depending on the quality of a neighboring vowel, Umotína (where variation is conditioned by the syllabicity of the following segment) does not exhibit shielding.

2.1.2 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" (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.[5]

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

[5]There is also a rare palatal nasal in Ese Ejja that varies very rarely with [j] (see Vuillermet 2012:169).

(4) Shielding-like behavior in Bolivian Ese Ejja

a.	**m**iya	[ˈ**m**ija] ∼ [**b**ija]	'2SG.ABS'
b.	**m**ei	[ˈ**mb**ej]	'stone'
b.	xe**m**i	[ˈxe**m**i] ∼ [ˈxe**b**i]	'squash sp.' (joco)
c.	**n**aba'ewi	[**n**aɓ̥aˈewi] ∼ [**d**aɓ̥aˈewi]	'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. /ɓ/; 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 Ese Ejja does not exhibit shielding (where an underlying *nasal consonant* can be realized as an *oral stop*), but rather a different form of contrast enhancement (where an underlying *oral stop* can be realized as a *nasal consonant*).

2.1.3 Local summary

This subsection has verified that if shielding exists in a given language, so does a V–Ṽ contrast.

An anonymous reviewer raises a worry that 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 occurs? 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 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, and dos Anjos 2011 on Katukina, among many others).

Vocalic nasality is not contrastive in any of the languages cited in the previous paragraph, 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.[6]

2.2 Analysis

We can now outline several desiderata for a successful analysis of shielding. First, in order to correctly predict that shielding should only occur in languages that license a contrast in vocalic

[6] In addition, an anonymous reviewer notes that we would expect to find careful transcription of nasals and voiced stops in these descriptions, as nasals and voiced stops contrast in English, Portuguese, *etc*.

nasality, the analysis of shielding must be able to reference facts about a language's phonemic inventory. Second, phonology must be able to 'see' the output of the phonetic grammar (an argument familiar from Jun 1995, *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.

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), as *NV and *VN are not sensitive to the structure of a language's larger vocalic inventory. A claim that *NV or *VN motivates shielding predicts that shielding could occur in any language – regardless of whether or not it licenses a contrast in vocalic nasality. Since this prediction is incorrect, *NV and *VN cannot be the right constraints to motivate shielding.[7]

In this article I adopt a version of Dispersion Theory (Flemming 2002 *et seq.*), which satisfies both of the criteria described above. To show how the theory provides an an account of the typology of environmental shielding, I begin with an analysis of the Karitiâna pattern, repeated below as (5).

(5) Shielding in Karitiâna (Storto 1999:25-26)
  a. /m/ → [mb] / Ṽ_V, #_V
     ex. /ã**m**o/ → [ã**mb**o] 'to climb'
  b. /m/ → [bm] / V_#, V_Ṽ
     ex. /ka**m**/ → [ka**bm**˺] 'now'
  c. /m/ → [bmb] / V_V
     ex. /api**m**ik/ → [api**bmb**ik˺] 'to pierce'
  d. /m/ → [m] / *elsewhere*
     ex. /ã**m**ãŋ/ → [ã**m**ãŋ˺] 'to plant'

I assume that shielding is motivated by a MINDIST constraint that requires the contrast between oral and nasal vowels to be sufficiently distinct. MINDIST constraints are markedness constraints that set thresholds of distinctiveness for a given contrast, and assign violations to contrasts that are insufficiently distinct (see Flemming 2002 *et seq.*). For example, we might imagine that in Karitiâna there is a MINDIST constraint requiring oral and nasal vowels to be maximally different: an oral vowel must be fully nasal and nasal vowel must be fully nasal for sufficient distinctiveness. This MINDIST constraint is formalized as $\text{NASDUR}_{100\%}$ (6).

(6) MINDISTV–Ṽ = $\text{NASDUR}_{100\%}$: 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. One * for each violating pair.

A contrast that satisfies $\text{NASDUR}_{100\%}$ is the fully oral vowel in [mba] (7a) versus the fully nasal vowel in [mã] (7c): the oral vowel is fully oral and the nasal vowel is fully nasal, so the contrast between them is sufficiently distinct. A pair that violates NASDUR is the nasalized oral vowel in [m$^{\tilde{a}}$a] (7b) versus the fully nasal vowel in [mã] (7c): the oral vowel is marked by some degree of acoustic nasality, so the contrast between it and a nasal vowel is not sufficiently distinct. (Throughout,

[7] An anonymous reviewer suggests that the analysis involving constraints like *NV and *VN could be saved if [±nasal] is only specified when a V–Ṽ contrast is present. To the extent that this proposal is successful, it underscores the major argument of this article: that any successful analysis of shielding must in some way explicitly reference contrast. The proposal however cannot account for the further generalizations outlined in Section 3; see Section 5.1 for discussion.

coarticulatory nasalization is denoted with a superscripted nasal vowel.)

(7) Comparisons between oral and nasal vowels

a. Fully oral vowel:

b. Nasalized oral vowel:

c. Fully nasal vowel:

Whether or not (7b–c) is modified in order to satisfy NASDUR$_{100\%}$, and how, depends on the ranking of other constraints. One way to satisfy NASDUR$_{100\%}$ is through neutralization: if both /ma/ and /mã/ are realized as [mã], there is no V–Ṽ contrast, and NASDUR$_{100\%}$ is vacuously satisfied. I assume that neutralization violates MAX[-nasal] (8).[8]

(8) MAX[-nasal]: one * for each [-nasal] value present in the input that is absent in the output.

Another way to satisfy NASDUR$_{100\%}$ is through shielding. By oralizing part of a nasal consonant (as in (7a)), the neighboring oral vowel is rendered fully oral, which satisfies NASDUR$_{100\%}$. I assume that shielding results in the violation of either a markedness or a faithfulness constraint, depending on the allophone that is produced: a nasal contour segment (e.g. /ma/ → [mba]) violates *CONTOUR (9), and a fully oral segment (e.g. /ma/ → [ba]) violates MAX[+nasal] (10).

(9) *CONTOUR: one * for each nasal contour consonant (i.e. [mb], [bm], [bmb], or each segment linked to both [+nasal] and [-nasal]).

(10) MAX[+nasal]: one * for each [+nasal] value present in the input that is absent in the output.

As shown in (11), when NASDUR$_{100\%}$ is high-ranked, whether or not shielding occurs depends on the relative ranking of the constraints that disprefer shielding (for brevity, only *CONTOUR is shown) with respect to those that disprefer neutralization (MAX[-nasal]). Note also that in (11) I assume the activity of NASALIZE, an undominated markedness constraint that requires vowels adjacent to nasal consonants to be nasalized in the vicinity of the nasal. When a nasal vowel neighbors a nasal consonant (e.g. /mã/), NASALIZE is automatically satisfied as the entire vowel is nasal; when an oral vowel neighbors a nasal consonant, NASALIZE is satisfied if coarticulatory nasalization (marked with a superscripted nasal vowel) is present. For now I leave aside questions of how much coarticulation is necessary to satisfy NASALIZE. For further discussion, see Section 3.3.

[8]Note that Flemming (2002) does not use Input-Output (IO) faithfulness constraints in his single-level version of Dispersion Theory, as the introduction of MAXCONTRAST, a positively evaluated constraint that favors contrast maintenance, renders them unnecessary (and in fact undesirable; see Flemming 2002:33–35 for discussion). The phenomena at issue here are however most transparently analyzed by making reference to input-output mappings and the faithfulness constraints that regulate them. In this domain, at least, the inclusion of IO faithfulness constraints seems to render MAXCONTRAST unnecessary. I leave a reconciliation of Flemming (2002) and the current analysis to future work.

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

	/ma/ /mã/	NASALIZE	NASDUR$_{100\%}$	MAX[-nasal]	*CONTOUR
	a. [ma] [mã]	*!			
	b. [m$^{\tilde{a}}$a] [mã]		*!		
☞	c. [mba] [mã]				*
☞	d. [mã] [mã]			*	

Candidate (11a) fatally violates NASALIZE, as the nasal-adjacent oral vowel does not bear any amount of nasal coarticulation. Candidate (11b) fatally violates NASDUR$_{100\%}$, as the nasalized oral vowel is insufficiently distinct from a nasal vowel (as per the definition in (6)).[9] For concreteness, I assume that the introduction of coarticulatory nasalization does not violate any faithfulness constraints, i.e. MAX[-nasal] or IDENT[±nasal]. More generally, I assume throughout that input-output faithfulness constraints only regulate *contrastive properties*. As coarticulatory nasalization is crosslinguistically non-contrastive (no known language contrasts [ma] with [m$^{\tilde{a}}$a]), no faithfulness constraint penalizes its introduction. Presumably, restrictions on the distribution of coarticulatory nasalization are regulated by other constraints: in (11), for example, if NASDUR$_{100\%}$ $\gg$ NASALIZE, coarticulatory nasalization is avoided to render contrasts in vocalic nasality sufficiently distinct.

Candidate (11c), the enhancement candidate, violates *CONTOUR; candidate (11d), the neutralization candidate, violates MAX[-nasal] (as /ma/ maps to [mã]). In order for the enhancement candidate to win, as in Karitiâna and other shielding languages, *CONTOUR (and other constraints that penalize shielding) must be demoted beneath MAX[-nasal]. The other repair – neutralization of the insufficiently distinct contrast – is discussed further in Section 4.

For speakers of languages that lack a contrast in vocalic nasality, NASDUR$_{100\%}$ is irrelevant: the constraint can only be evaluated when oral and nasal vowels contrast. As shown in the tableau in (12), modification of NV sequences in languages *without* a contrast in vocalic nasality is not motivated by NASDUR$_{100\%}$, and therefore blocked by other 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.[10]

(12)

	/ma/	NASALIZE	NASDUR$_{100\%}$	*CONTOUR	MAX[-nasal]
	a. [ma]	*!			
☞	b. [m$^{\tilde{a}}$a]				
	c. [mba]			*!	
	d. [mã]				*!

Up to this point, I have assumed that oral vowels adjacent to fully nasal consonants are nasalized to some degree. While the phonetics of coarticulatory nasalization do vary by language (see Section 3.1), 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. Butcher 1999 on Australian languages). By contrast, oralization of nasal vowels adjacent to oral consonants is rarely described, and

[9]Partially nasalized vowels do not violate *CONTOUR: as defined in (9), *CONTOUR only penalizes consonants.

[10]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 either variability in the outcome (noted in 26/66 descriptions consulted; see Appendix B) or extrapolation from other kinds of coarticulation in the language.

in the one case I know of (French, Cohn 1990), oralization is brief. For this article, then, 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. 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 absent, for example, shielding just would not be motivated.

3 Asymmetries in the typology

Looking beyond Karitiâna, we find that languages differ in unpredictable ways as to the sets of allophones that shielding can produce. The only generalization apparent in (13) is that if a language licenses medionasals (e.g. [bmb]), it also licenses other contours.

(13) 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. This section shows that asymmetries in the typology of shielding are correctly predicted by the phonetic asymmetries. The major generalization that emerges is the following: if a language licenses shielding in a context where contrasts in vocalic nasality are expected to be relatively distinct, it also licenses shielding in all contexts where contrasts in vocalic nasality are expected to be less distinct. Section 3.3 shows that this cross-linguistic generalization is predicted by a contrast-based analysis, and Section 3.4 suggests that the generalization also holds within the grammars of individual languages.

3.1 The phonetics of nasal coarticulation

It is well-known that languages display asymmetries in the direction and extent of nasal coarticulation. In (14), 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. This survey draws mostly on preexisting 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 (14) 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.[11] 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, 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.

(14) Coarticulatory nasalization survey

Type	Language	NV	$VN]_\sigma$	$V]_\sigma N$	Source
1	Hindi	-	+		Ohala (1975:323)
	St. Lucian Creole	-	+	-	Bhatt & Nikiema (2000)
2	Agwagwune	100%		15%	Huffman (1988)
	Akan	74%		92%	Huffman (1988)
	Arabic (Cairene)	72%	38%		Jeong (2012: 450)
	Chinese (Standard)		+	-	Chen (2000)
	English (American)[12]	82%	76%		Flege (1988:532); see also Cohn (1990:143–147)
	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)

Two generalizations characterize the data in (14). First, perseveratory coarticulation (NV) is more extensive than heterosyllabic anticipatory coarticulation ($V]_\sigma N$). The sole apparent 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 required to determine 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 characterizing (14) is that tautosyllabic anticipatory coarticulation ($VN]_\sigma$) is more extensive than heterosyllabic anticipatory coarticulation ($V]_\sigma N$). While only four languages in (14) demonstrate this, the tautosyllabic vs. heterosyllabic asymmetry has been documented more widely

[11] 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.

[12] The status of American English as a Type 2 language is debatable; results from Chen et al. (2007) suggest that, for at least some speakers, the amount of nasalization in $VN]_\sigma$ is greater than that 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.

(see e.g. Krakow 1993 on English; Schourup 1973 and Herbert 1986 on a number of others).[13]

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 depends on the language. In *Type 1* systems (labeled as '1' in (14)), tautosyllabic anticipatory coarticulation is more extensive. In *Type 2* systems (labeled as '2' in (14)), either perseveratory coarticulation is more extensive, or the data necessary to determine this are not available.

Given these generalizations, we expect there to be two types of system that display asymmetries in nasal coarticulation. 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 ($V]_\sigma N$). In these diagrams and all that follow, the precise breakdown of a vowel into percent oral and percent nasal is for illustrative purposes only. What matters is only the asymmetries among the different contexts.

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

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

$V_{20\%}$	$\tilde{V}_{80\%}$	$N]_\sigma$

b. Perseveratory coarticulation (NV)

N	$\tilde{V}_{60\%}$	$V_{40\%}$

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

$V_{60\%}$	$\tilde{V}_{40\%}$	$]_\sigma N$

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)

N	$\tilde{V}_{80\%}$	$V_{20\%}$

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

$V_{40\%}$	$\tilde{V}_{60\%}$	$N]_\sigma$

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

$V_{60\%}$	$\tilde{V}_{40\%}$	$]_\sigma N$

Assuming that the greater the degree 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 are 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

[13] It isn't crucial that the difference between the two classes of nasals is one of syllable position (onset vs. coda). I use syllable-based notation here because this is the notation used in the majority of studies on nasal coarticulation.

the heterosyllabic anticipatory context (so Δ V]$_\sigma$N–$\tilde{V}$]$_\sigma$N $>$ Δ NV–N$\tilde{V}$, Δ VN]$_\sigma$–$\tilde{V}$N]$_\sigma$).[14] In Type 1 systems, we expect for contrasts in vocalic nasality to be more distinct in the perseveratory context than in the tautosyllabic anticipatory context (Δ NV–N$\tilde{V}$ $>$ Δ VN]$_\sigma$–$\tilde{V}$N]$_\sigma$); in Type 2 systems, we expect for these contrasts to be more distinct in the tautosyllabic anticipatory context than they are in the perseveratory context (Δ VN]$_\sigma$–$\tilde{V}$N]$_\sigma$ $>$ Δ NV–N$\tilde{V}$).

(17) Expected distinctiveness of vocalic nasality contrasts

a. Type 1 systems: Δ V]$_\sigma$N-$\tilde{V}$]$_\sigma$N $>$ Δ NV-N$\tilde{V}$ $>$ Δ VN]$_\sigma$-$\tilde{V}$N]$_\sigma$

b. Type 2 systems: Δ V]$_\sigma$N-$\tilde{V}$]$_\sigma$N $>$ Δ VN]$_\sigma$-$\tilde{V}$N]$_\sigma$ $>$ Δ NV-N$\tilde{V}$

If shielding is a strategy to maximize cues to contrasts in vocalic nasality, we would expect the phonetic asymmetries outlined above to yield an implicational generalization regarding the contexts in which shielding occurs: if a given language licenses shielding in a context where a contrast in vocalic nasality is *more* distinct, 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 in the perseveratory or tautosyllabic anticipatory contexts. We do not expect to find systems in which shielding applies in limited contexts, to preserve only the more distinct contrasts in vocalic nasality (e.g. in the V]$_\sigma$N context only).

3.2 Testing the predictions

The predicted and non-predicted shielding patterns are in (18). A checkmark indicates the presence of shielding in the given context; the absence of a checkmark indicates its absence. Note that while (18) represents predictions about the typology of shielding, the asymmetries in nasal coarticulation that generate these predictions come from a set of languages that do not license shielding. The linking assumption is that the phonetic asymmetries documented above represent the full range of possible variation in coarticulatory patterns; while they are only visible in non-shielding languages, the grammar more generally is constrained to generate only these asymmetries.

(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, 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, is predicted because

[14] Here, Δ x–y = "the perceptual distance between x and y."

in Type 2 systems the perseveratory context is where contrasts in vocalic nasality are the least distinct. Pattern (18c), with shielding in 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 2 systems. And finally, pattern (18d), where shielding occurs in all contexts, 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), nine shield in both contexts (21), and five shield in all contexts (22).[15] Recall that the exact allophones produced by shielding vary by language in unpredictable ways: for example, while Chiriguano 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 Appendix B.

(19) Shielding in VN]$_\sigma$ only: 7 lgs., including Nadëb (Barbosa 2005):
  a. /m/ → [bm] / V_C, V_# [ʃə**dn**] 'hair' (Barbosa 2005:45; translation mine)
  b. /m/ → [m] / elsewhere [**n**apiɟ˺] 'sieve' (Barbosa 2005:42; t.m.)

(20) Shielding in NV only: 45 lgs., including Chiriguano (Dietrich 1986):
  a. /m/ → [mb] / _V [a**mb**oáku] 'I warm up' (Dietrich 1986:61; t.m.)
  b. /m/ → [m] / elsewhere [ã**m**õtãta] 'I toughen up' (Dietrich 1986:61; t.m.)

(21) Shielding in VN]$_\sigma$ and NV: 8 lgs., including Karo (Gabas 1998):
  a. /m/ → [bm] / V_C, V_# [koˈɾɛ**bm**] 'also' (Gabas 1998:16; t.m.)
  b. /m/ → [mb] / _V [tahˈ**mb**ək] 'all of them' (Gabas 1998:14; t.m.)
  c. /m/ → [m] / elsewhere [ˈ**n**ə̃p˺] 'cable' (Gabas 1998:14; t.m.)

(22) Shielding in all contexts: 6 lgs., including Kaingang (Cavalcante 1987):
  a. /m/ → [bm] / V_Ṽ, V_# [pãˈtɛ**dn**] 'surpass' (Cavalcante 1987:39; t.m.)
  b. /m/ → [mb] / #_V, Ṽ_V [ˈ**nd**o] 'arrow' (Cavalcante 1987:39; t.m.)
  c. /m/ → [bmb] V_V [koˈ**bmb**e] 'broth' (Cavalcante 1987:39; t.m.)
  d. /m/ → [m] / elsewhere [kaˈdnã**n**] 'to smooth' (Cavalcante 1987:39; t.m.)

The patterns in (18e–g) are not predicted to occur, as shielding occurs in the heterosyllabic anticipatory context only. As contrasts in vocalic nasality are expected to be relatively more distinct in the heterosyllabic anticipatory context, languages that shield in the heterosyllabic anticipatory context should also shield in the other two contexts. As predicted, these patterns are unattested.

3.3 Incorporating the asymmetries into the analysis

For the sake of analysis, I assume 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 assume that nasal vowels in the contexts listed below (VN]$_\sigma$, NV, and V]$_\sigma$N) are fully nasal.

(23) Assumed patterns of nasal coarticulation
  a. Tautosyllabic anticipatory coarticulation (VN]$_\sigma$)
    (i) Type 1: $V_{20\%}$ | $\tilde{V}_{80\%}$ | N]$_\sigma$

[15] An anonymous reviewer asks why shielding is found mostly in NV sequences. I don't know, but perhaps languages with Type 2 phonetics are more common, and many shield to avoid only the most imperiled V–Ṽ contrasts.

(ii) Type 2: $V_{40\%}$ $\tilde{V}_{60\%}$ $N]_\sigma$

b. Perseveratory coarticulation (NV)

(i) Type 1: N $\tilde{V}_{60\%}$ $V_{40\%}$

(ii) Type 2: N $\tilde{V}_{80\%}$ $V_{20\%}$

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

(i) Type 1: $V_{60\%}$ $\tilde{V}_{40\%}$ $]_\sigma N$

(ii) Type 2: $V_{60\%}$ $\tilde{V}_{40\%}$ $]_\sigma N$

The difference between the Type 1 and Type 2 patterns is due to a difference in the patterns of coarticulatory timing, which are themselves likely due to the activity of more general constraints on the coordination of gestures. While ultimately it would be desirable to build a theory that lays out the possible and preferred ways of coordinating velic gestures with other kinds of gestures, for present purposes it is sufficient to assume that there are only two possible kinds of coarticulatory pattern (those schematized in (23)) and that they arise due to a difference in the definition NASALIZE (see Section 2.2). The constraint that compels the Type 1 pattern is $\text{NASALIZE}_{\text{Type1}}$ (24); the Type 2 pattern is compelled by $\text{NASALIZE}_{\text{Type2}}$ (25).

(24) $\text{NASALIZE}_{\text{Type1}}$: assign one * for each…

a. $VN]_\sigma$ sequence where V is not at least 80% nasalized;

b. NV sequence where V is not at least 60% nasalized;

c. $V]_\sigma N$ sequence where V is not at least 40% nasalized.

(25) $\text{NASALIZE}_{\text{Type2}}$: assign one * for each…

a. NV sequence where V is not at least 80% nasalized;

b. $VN]_\sigma$ sequence where V is not at least 60% nasalized;

c. $V]_\sigma N$ sequence where V is not at least 40% nasalized.

Going forward I assume that one NASALIZE constraint is active in each language; the specific amounts of nasal coarticulation required in each context are parameterized on a language-specific basis. It is worth emphasizing at this point that NASALIZE is meant to function as a shorthand for whatever constraints compel nasal coarticulation, and is not meant to function in any way as a claim about how those constraints are defined. Presumably, any successful theory of the grammar of coarticulation needs to explain why certain contextual asymmetries are universal (e.g. more coarticulation in $VN]_\sigma$ than $V]_\sigma N$) and others are not (e.g. language-dependent amounts of coarticulation in NV and $VN]_\sigma$). NASALIZE does not do this – it would be possible, for example, to define a version of the constraint that requires more nasalization in $V]_\sigma N$ than in $VN]_\sigma$. But as our interest is not in how to derive universals of nasal coarticulation, but in what can be derived from them, the constraints in (24–25) are sufficient.

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% oral to be distinct from nasal vowels, for example, penalizes only the contrasts between oral vowels in (23a–b) and nasal vowels in those same environments.

A question arises here: when we talk about partially nasalized vowels, should they be described in terms of *percentage* or *absolute duration* of acoustic nasality? I will assume here that referring to the ratio of nasality in a vowel is relevant: although this has not been shown, 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. There is some evidence, however, that the absolute duration of acoustic nasality is also relevant to the perception of vocalic nasality. For example, Whalen & Beddor (1989) provide experimental evidence 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 asymmery: 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 (26).[16]

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

✓V-Ṽ , ✓Vː-Ṽː	*V-Ṽ, ✓Vː-Ṽː	✓V-Ṽ , *Vː-Ṽː
Irish, Hindi-Urdu, Lakkia, Navaho, Chipewyan, Tolowa, Auca, !Xu	Breton, Ojibwa, Delaware	

The analyses presented here make reference to ratios of nasality, not absolute duration. 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 the analysis.

3.3.1 Languages with shielding in all contexts

To analyze systems in which shielding occurs in all contexts, we need a MINDIST constraint that requires an oral vowel to be fully oral, and a nasal vowel to be fully nasal, for the contrast between them to be sufficiently distinct. This constraint is NASDUR$_{100\%}$ (27), repeated from (6).

(27) MINDISTV-Ṽ = NASDUR$_{100\%}$: 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.

When this constraint is high-ranked, all contrasts in vocalic nasality adjacent to a nasal consonant are dispreferred, as oral vowels are nasalized in these environments (see (23)). Thus even in the heterosyllabic context, shielding is motivated (28). (In (28), NASALIZE$_{\text{Type1/2}}$ is referred to as such because either NASALIZE$_{\text{Type1}}$ or NASALIZE$_{\text{Type2}}$ would derive the intended result.)

(28) Sample tableau: shielding in the heterosyllabic context

/amã/ /ãmã/	NASALIZE$_{\text{Type1/2}}$	NASDUR$_{100\%}$	MAX[-nasal]	*CONTOUR
a. [amã] [ãmã]	*!			
b. [a$^{\tilde{a}}$mã] [ãmã]		*!		
☞ c. [abmã] [ãmã]				*
d. [ãmã] [ãmã]			*!	

[16]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.

3.3.2 Languages with tautosyllabic anticipatory and perseveratory shielding

To analyze systems where shielding occurs in the tautosyllabic anticipatory and perseveratory contexts, I assume that some languages place less strict requirements on vocalic nasality contrasts. For example, a language might only require oral vowels to be 50% oral to be distinct from nasal vowels. A constraint enforcing this less stringent requirement is NASDUR$_{50\%}$ (29).

(29) MINDISTV-Ṽ = NASDUR$_{50\%}$: for a contrast in vocalic nasality to be sufficiently distinct, the oral vowel must be at least 50% 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$_{50\%}$ 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% oral; see (23). The result is that shielding is motivated in both the perseveratory and the tautosyllabic anticipatory contexts, as illustrated in (30–31). Because the oral vowel must be more than 50% nasal (as required by NASALIZE$_{\text{Type1/2}}$; cf. (30b), where a lesser amount of nasal coarticulation violates NASALIZE$_{\text{Type1/2}}$), the contrast between it and a nasal vowel does not satisfy NASDUR$_{50\%}$. In (30–31) and the tableaux that follow, a subscripted percentage either preceding or following the vowel denotes the percentage of the vowel that is oral.

(30) NASDUR$_{50\%}$ motivates shielding in the perseveratory context

/ma/	/mã/	NASALIZE$_{\text{Type1/2}}$	NASDUR$_{50\%}$	MAX[-nasal]	*CONTOUR
a. [ma]	[mã]	*!			
b. [m$^{\tilde{a}}$a$_{>50\%}$]	[mã]	*!			
c. [m$^{\tilde{a}}$a$_{<50\%}$]	[mã]		*!		
☞ d. [mba]	[mã]				*
e. [mã]	[mã]			*!	

(31) NASDUR$_{50\%}$ motivates shielding in the tautosyllabic anticipatory context

/am/	/ãm/	NASALIZE$_{\text{Type1/2}}$	NASDUR$_{50\%}$	MAX[-nasal]	*CONTOUR
a. [am]	[ãm]	*!			
b. [$_{<50\%}$a$^{\tilde{a}}$m]	[ãm]		*!		
☞ c. [abm]	[ãm]				*
d. [ãm]	[ãm]		*!		

In the heterosyllabic anticipatory context, contrasts between the less-nasalized (>50%) oral vowels and fully nasal vowels do not violate NASDUR$_{50\%}$, so shielding is not motivated (32).

(32) NASDUR$_{50\%}$ does not motivate shielding in the heterosyllabic anticipatory context

/amã/	/ãmã/	NASALIZE$_{\text{Type1/2}}$	NASDUR$_{50\%}$	MAX[-nasal]	*CONTOUR
a. [amã]	[ãmã]	*!			
☞ b. [$_{>50\%}$a$^{\tilde{a}}$mã]	[ãmã]				
c. [abmã]	[ãmã]				*!
d. [ãmã]	[ãmã]		*!		

3.3.3 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 only be 30% oral, for them to be sufficiently distinct from nasal vowels. While this sounds minimal, it's not uncommon. For example, vocalic nasality is contrastive in the perseveratory context in French, even though oral vowels are significantly nasalized following nasal consonants (data in (14)). A constraint enforcing this requirement, NASDUR$_{30\%}$, is defined in (33).

(33) MINDISTV-Ṽ = NASDUR$_{30\%}$: for a contrast in vocalic nasality to be distinct, the oral vowel must be at least 30% oral and the nasal vowel fully nasal. Assign one violation for each violating pair.

Which contrast violates NASDUR$_{30\%}$ depends on system type. For Type 1 systems: contrasts in the tautosyllabic anticipatory context violate NASDUR$_{30\%}$, as oral vowels in this context are less than 30% oral. Contrasts in the perseveratory and heterosyllabic anticipatory contexts do not violate NASDUR$_{30\%}$, as oral vowels in these contexts are more than 30% oral. Thus for Type 1 systems, NASDUR$_{30\%}$ motivates shielding in the tautosyllabic anticipatory context only (34).

(34) Type 1: NASDUR$_{30\%}$ motivates shielding in the tautosyllabic anticipatory context

/am/	[ãm]	NASALIZE$_{Type1}$	NASDUR$_{30\%}$	MAX[-nasal]	*CONTOUR
a. [am]	[ãm]	*!			
b. [$_{>30\%}$a$^{\tilde{a}}$m]	[ãm]		*!		
☞ c. [abm]	[ãm]				*
d. [ãm]	[ãm]			*!	

For Type 2 systems: only contrasts in the perseveratory context violate NASDUR$_{30\%}$, as oral vowels in the perseveratory context are less than 30% oral (35). Contrasts in the tautosyllabic and heterosyllabic anticipatory contexts do not violate NASDUR$_{30\%}$, as oral vowels are less nasalized.

(35) Type 2: NASDUR$_{30\%}$ motivates shielding in the perseveratory context

/ma/	/mã/	NASALIZE$_{Type2}$	NASDUR$_{30\%}$	MAX[-nasal]	*CONTOUR
a. [ma]	[mã]	*!			
b. [m$^{\tilde{a}}$a$_{<30\%}$]	[mã]		*!		
☞ c. [mba]	[mã]				*
d. [mã]	[mã]			*!	

At this point it is worth reiterating that the percentages used in all 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 (14). Regardless of the exact extent of coarticulatory nasalization or the exact point at which nasalization in an oral vowel renders it indistiguishable from a nasal vowel, setting thresholds of distinctiveness with MINDIST constraints allows us to derive those and only those shielding patterns that obey the existing implicational laws.

3.3.4 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. MINDIST constraints naturally capture this generalization because they set thresholds at which contrasts are sufficiently distinct. If some contrast *x–y* violates a given MINDIST constraint in some context C_1, then *x–y* will also violate that MINDIST constraint in all contexts in which *x–y* is equally or less distinct than it is in C_1. As it is impossible to define a 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.

3.4 Language-internal asymmetries

The contrast-based analysis correctly predicts that when a language limits shielding to certain contexts, it occurs in those contexts where vocalic nasality contrasts are the least distinct. This subsection provides further evidence that this prediction is correct from asymmetries in Krenak (Pessoa 2012), Aguaruna (Overall 2007), and Karajá (Ribeiro 2012). These cases were selected as they are two asymmetries supported by detailed description; for discussion of others, see Appendix B.

3.4.1 The role of stress in Krenak

In Krenak (Macro-Ge; Pessoa 2012), shielding occurs in all contexts, but more frequently in unstressed syllables than in stressed syllables. (Shielding in the tautosyllabic anticipatory context, however, is more frequent word-finally – perhaps because consonants are lengthened in this position, as suggested by Figure 1 below, and are better hosts for nasal contours.) Examples are in (36): (a) illustrates shielding in the perseveratory context before an oral vowel vs. its absence before a nasal vowel, and (b) illustrates shielding in the tautosyllabic anticipatory context vs. its absence after a nasal vowel. Gloss translations are mine.

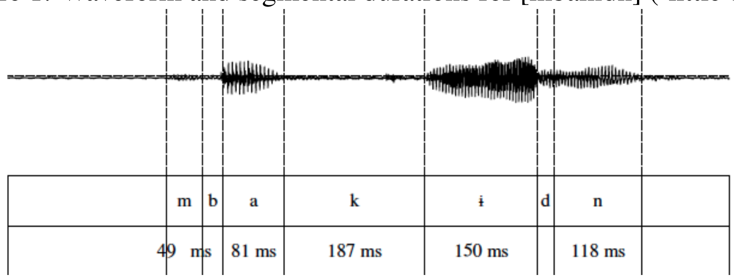
(36) Shielding in Krenak (2012:114–121)

a.	/a**m**iʒik/	→	[ˌa**mb**iˈʒik]	'manioc'	cf. [ˌa**m**ɜ̃ˈŋgut] 'food'
b.	/tõnɔ**n**/	→	[tõˈndɔ**dn**]	'small'	cf. [hiˈnũ**n**] 'his/her arm'

Why should a shielding process preferentially apply in stressless syllables? One answer banks on a potential link between stress and duration: perhaps stressed vowels are longer than stressless vowels. Primary stress in Krenak is word-final (Pessoa 2012:113), and some evidence for final lengthening 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^{b}akɨ$^{\text{d}}$n] ('little bird'), from Pessoa p. 96, illustrates: at 150 ms., word-final [ɨ] is almost twice as long as non-final [a] (Figure 1). This difference likely cannot be traced to an inherent durational asymmetry between [ɨ] and [a], as low vowels are generally longer than high ones (Lehiste 1976).

If we assume that the amount of nasal coarticulation induced on a vowel adjacent to a nasal consonant is consistent regardless of the vowel's length (i.e. the velum gesture is frequently longer than the oral closure of the nasal consonant, but does not depend on the length of other gestures that coincide with and/or surround it), 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 might

Figure 1: Waveform and segmental durations for [mbakɨdn] (‘little bird’)



only take up 50% of a long vowel, for example (37), that same amount of nasal coarticulation will take up comparatively more of a shorter vowel (38).

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

a. N [$\tilde{V}_{50\%}$ | $V_{50\%}$]

b. N [$\tilde{V}$]

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

a. N [$\tilde{V}_{75\%}$ | $V_{25\%}$]

b. N [$\tilde{V}$]

It is possible to motivate shielding in only (38) by defining a MINDIST constraint that considers the contrast in (37), but not the contrast in (38), sufficiently distinct. $\text{NASDUR}_{50\%}$ (32) suits this purpose. As the oral vowel in (37) is only 50% nasal, $\text{NASDUR}_{50\%}$ is satisfied (39). (In (39–40), I assume that NASALIZE compels the patterns of coarticulation diagrammed in (37–38).)

(39) Shielding is not motivated when vowels are long

/maː/ /mãː/	NASALIZE	$\text{NASDUR}_{50\%}$	MAX[-nasal]	*CONTOUR
a. [maː] [mãː]	*!			
☞ b. [m$^{\tilde{a}}$a$ː_{50\%}$] [mãː]				
c. [mbaː] [mãː]				*!
d. [mãː] [mãː]			*!	

The contrast in (38) violates $\text{NASDUR}_{50\%}$, however, as the oral vowel is only 25% nasal. Shielding is therefore motivated for short, but not long, vowels (40).

(40) Shielding is motivated when vowels are short

/ma/ /mã/	NASALIZE	$\text{NASDUR}_{50\%}$	MAX[-nasal]	*CONTOUR
a. [ma] [mã]	*!			
b. [m$^{\tilde{a}}$a$_{25\%}$] [mã]		*!		
☞ c. [mba] [mã]				*
d. [mã] [mã]			*!	

The fact that Krenak exhibits greater frequency of shielding in stressless syllables is predicted by a contrast-based account: a given amount of nasal coarticulation will render a stressless (or shorter) oral vowel comparatively less distinct from a nasal vowel than it will a stressed (or longer) oral vowel. As was the case for the contextual asymmetries documented above, when shielding targets only some contexts, it targets those contexts in which contrasts in vocalic nasality are less distinct.

3.4.2 The role of vowel quality in Aguaruna and Karajá

In Karajá (Macro-Ge, Ribeiro 2012), shielding[17] occurs only in the perseveratory context. It 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).[18]

(41) Shielding in Aguaruna

a.	/**mam**a/	→	[**mam**á]	'mother'
b.	/**n**usi/	→	[**d**úsɨ] ∼ [**nd**úsɨ]	'peanut'
c.	/**n**atsa/	→	[**d**átsa] ∼ [**nd**átsa]	'youth'

The vocalic inventories of Karajá (Ribeiro 2012:86) and Aguaruna (Overall 2007:40) are provided in (42) and (43), respectively. Note that, in both languages, /a/ is the only low vowel.

(42) Vocalic inventory of Karajá

i	ɨ	u	ĩ		
ɪ	ᵻ	ʊ			
e	ɘ	o	ə̃		õ
ɛ	(ə)	ɔ			
	a			ã	

(43) Vowel inventory of Aguaruna

i	ɨ	u	ĩ	ɨ̃	ũ
	a			ã	

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 the contrast between [a] and its nasal counterpart to be the most distinct. 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, 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. Here too, the subset of contexts targeted by shielding in Karajá and

[17] Ribeiro (2012) claims [m] and [n] are allophones of /b/ and /d/; the data are also compatible with a shielding analysis, in which [b] and [d] are allophones of [m] and [n].

[18] 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 Appendix B for discussion of this and other points.

Aguaruna are those contexts in which contrasts in vocalic nasality are expected to be less distinct.[19]

4 Extensions: the typology of neutralization

Faced with an insufficiently distinct contrast, a language has two options: preserve the contrast through enhancement, or neutralize it. This article has focused only on enhancement, but the analysis of enhancement makes predictions regarding the typology of neutralization as well. Under a contrast-based analysis, shielding and neutralization of vocalic nasality contrasts are motivated by the same set of MINDIST constraints. If MAX[-nasal] dominates either *CONTOUR, as well as other constraints that disprefer shielding, the language will shield (as shown throughout Section 3); if *CONTOUR dominates MAX[-nasal], the language will neutralize (44).

(44) Neutralization when *CONTOUR $\gg$ MAX[-nasal]

/ma/ /mã/	NASALIZE	NASDUR$_{100\%}$	*CONTOUR	MAX[-nasal]
a. [ma] [mã]	*!			
b. [m$^{\text{ã}}$a] [mã]		*!		
c. [mba] [mã]			*!	
☞ d. [mã] [mã]				*

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 should govern both. 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: 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 both enhancement and neutralization targeting *x–y* in C_1 must also target *x–y* in C_2 (see also Flemming 2008: 32ff).

To test this prediction, I conducted a survey composed of all descriptive grammars from PL5000–PM7875 available in MIT's Hayden Library, as well as various online sources. Of the languages in the sample, 98 licensed contrasts in vocalic nasality. In 32, contextual restrictions on the distribution of these contrasts were explicitly discussed. Asymmetries in the typology of neutralization, for the most part, directly mirror asymmetries in the typology of shielding (45). For a list of languages surveyed and information about the contexts of neutralization (where applicable), see appendix D.

[19] An anonymous reviewer notes that the pattern in Karajá could also 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).

(45) Results from the neutralization survey

	Context of neutralization			Predicted?	Attested?	Example
	V/N_	V/_N]$_\sigma$	V/_]$_\sigma$N			
a.	✓			Yes	Yes (20)	Vai (Welmers 1976)
b.		✓		Yes	Yes (3)	Gbeya (Samarin 1966)
c.	✓	✓		Yes	Yes (2)	Kiowa (Watkins 1984)
d.	✓	✓	✓	Yes	Yes (6)	Kana (Ikoro 1996)
e.		✓	✓	No	Yes (2)	Tinrin (Osumi 1995)
f.	✓		✓	No	No	
g.			✓	No	No	

The two attested systems in (45e) are not predicted to exist, but it is possible to show that these counterexamples are only apparent. There is substantial evidence that Tinrin (Osumi 1995) has (or had) a process of regressive nasal spreading. While sequences of oral (VV) and nasal (ṼṼ) vowels are possible, there are restrictions on sequences of oral and nasal vowels (Osumi 1995:24): a nasal vowel can precede an oral vowel (ṼV), but an oral vowel cannot precede a nasal vowel (*VṼ). This is exactly what we expect from a language that licenses regressive [+nasal] spreading. Further evidence for a process of regressive nasal spreading comes from restrictions on vowel sequences across approximants ([w], [r∼ɾ], and [ɽ]). Across these segments, vowels agree for nasality in the vast majority (91%, or 305/335) of cases (46). The existing mismatches are almost exclusively ṼRV: the general absence of VRṼ is, again, consistent with the activity of regressive [+nasal] spreading.

(46) Vowel sequences across approximants in Tinrin

	Match	Mismatch	
		ṼRV	VRṼ
#	305	26	4
Total	**305**	**30**	

Across voiceless obstruents, the rate of matches is lower (43/66, or 65%), suggesting that spreading applies less consistently (if at all) across stops. More frequent application across sonorants is consistent with implicational laws governing the typology of nasal spreading (e.g. Schourup 1973, Walker 2000). The other language with neutralization of vowel nasality contrasts in both anticipatory contexts is Xârâcùù (Lynch 2002b), a relative of Tinrin. While there is less data available, the counts largely resemble the Tinrin counts: vowels match for nasality in most VRV sequences (96% match, or 48/50), but they are less likely to match across voiceless stops (72% match, or 23/32).[20]

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.[21] 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

[20] For Tinrin, the counts in (46) 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 Xàràcûû, all relevant forms have been included for both counts. For both languages, forms transcribed variably (i.e. VRV on one page but ṼRV on another) have been excluded.

[21] To be clear, I assume here that unbounded nasal spreading is not motivated by constraints on contrast. While there is not space to develop a full analysis of the Tinrin and Xâracùù 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.

pattern that possibility of nasal spreading adds to the predicted typology of neutralization.

From the current survey, the prediction that the typologies of shielding and neutralization should parallel one another appears to be borne out: all apparent counterexamples have a plausible reanalysis. (Of course, to verify the prediction more fully, a larger sample size would be necessary.)

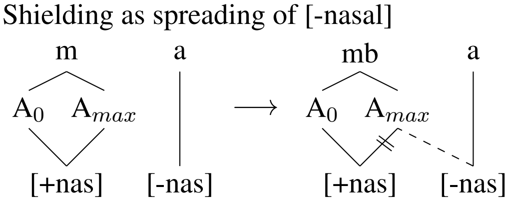
5 Are there alternatives?

So far, this article has shown that analyzing environmental shielding as contrast preservation makes a set of strong and accurate predictions. But is it possible to account for the existing set of generalizations without appealing directly to constraints on contrast? This section considers three alternative analyses. The first, discussed in Section 4.1, claims that shielding arises from spreading of [-nasal] (e.g. Storto 1999:26–31). The second, discussed in Section 4.2, uses CUE constraints (e.g. Boersma 2009) instead of directly referencing contrast; the third, discussed in Section 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 in this article. 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.

5.1 Spreading of [-nasal]

The only existing alternative analysis of shielding claims that it 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), perhaps motivated by a ban on nasal consonants followed by oral vowels (*NV). A case of shielding in the perseveratory context, for example, is analyzed as (47). (Below, A_0 denotes the closure phase of the stop, and A_{max} denotes the release; see Steriade 1993a on aperture positions.)

(47) Shielding as spreading of [-nasal]



A spreading-based analysis, however, 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 is possible to solve this problem by allowing [-nasal] to spread only if [±nasal] is contrastive for vowels, this analysis has no explanation for contextual asymmetries in the shielding typology (Section 3), nor does it predict that the typologies of shielding and contextual neutralization should mirror one another (Section 4). (For additional arguments that [-nasal] cannot spread, see Steriade 1993b.)

5.2 CUE constraints

The proposed analysis of shielding claims that it is crucial to explicitly reference contrast by appealing to acoustic properties that cue phonemic contrasts. Other approaches appeal to acoustic properties that cue the presence of individual feature values or segments, and do not reference contrast. Here I explore how one such model, Boersma's (2009 *a.o.*) Parallel Bidirectional Phonology and Phonetics (BiPhon) model, might account for the data in this article. We focus here on CUE constraints, which penalize correspondences between abstract phonological units (in slashes) and their phonetic realizations (in square brackets).[22] A schematic CUE constraint is in (48); this constraint penalizes a correspondence between a vowel that is [-nasal] and a vowel that is *X%* nasalized.

(48) */V/[*X%+ nasalized*]: assign one violation for each oral vowel that is *X%+* nasalized.

As CUE constraints interact with more traditional markedness and faithfulness constraints, instances of (48) can motivate shielding and neutralization. Violations of */V/[*60%+ nasalized*], for example, can be ameliorated through neutralization (mapping the nasalized oral vowel to a nasal one) or shielding (eliminating the nasalization), depending on the ranking of the relevant constraints.

While a model that incorporates CUE constraints might be capable of accounting for the existing contextual asymmetries in shielding, as well as their parallels in the typology of neutralization, it cannot 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: (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. Further developments may change this conclusion, but at present the inability to refer to contrast renders the BiPhon model unable to account for the full set of generalizations presented in this article.

5.3 Channel bias

The final alternative I discuss holds that shielding emerges 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. For example, consider a system in which all syllables are open, and shielding occurs in the perseveratory context only (49).

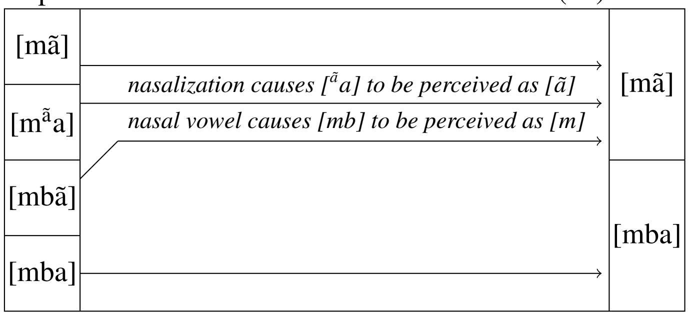
(49) Hypothetical perseveratory shielding system
   a. Oral and nasal vowels contrast after voiceless consonants: ✓pã, ✓pa
   b. Only oral vowels may follow NCs: ✓mba, *mbã
   c. Only nasal vowels may follow Ns: ✓mã, *ma

The system in (49) could have developed from an earlier stage in which nasal and voiced prenasalized consonants were contrastive. Over time, however, oral vowels following nasal consonants could have been confused with, and reinterpreted as, nasal vowels ([m$^{\tilde{a}}$a] → /mã/). In addition, prenasalized consonants preceding nasal vowels could have been reinterpreted as plain nasal conso-

[22]For a general summary of how CUE constraints figure within the larger BiPhon model, see Boersma (2009).

nants ([mbã] → /mã/; on cues to the N vs. NC contrast see Beddor & Onsuwan 2003). The resulting system is one in which nasal and prenasalized consonants are in complementary distribution (50).

(50) Proposed historical source of the distribution in (49)



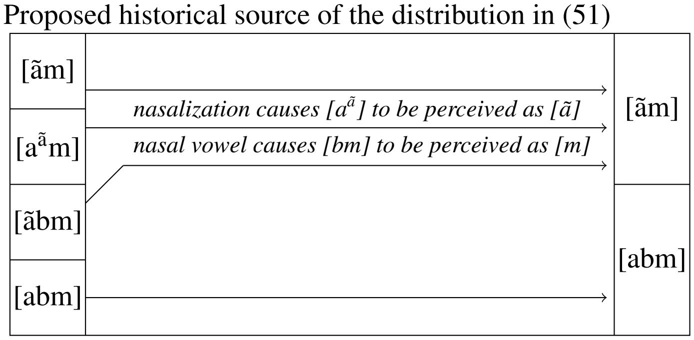
This account, however, faces a number of problems in accounting for some of the more complex patterns attested in the typology. First, it is unclear how the theory would be able to account for systems in which shielding occurs in only a subset of the contexts in which it could possibly occur. Consider for example those systems in which shielding occurs in only the tautosyllabic anticipatory 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 (51).

(51) Hypothetical tautosyllabic anticipatory system

a. Oral and nasal vowels contrast following oral consonants: ✓pã, ✓pa
b. Oral and nasal vowels contrast following nasal consonants: ✓mã, ✓ma
c. Only oral vowels may precede CNs: ✓abm, *ãbm
d. 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 (52) 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^{ã}m] → /ãm/). Preoralized stops following nasal vowels would be confused with, and reinterpreted as, plain nasals ([ãbm] → /ãm/).

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



But if the system in (51) 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 any language with the shielding pattern in (52)? To explain why a language that displays the shielding pattern in (52) 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 (53), for example, would prevent both [bma] and [abma] from surfacing, but crucially allow [abm] to exist.

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

But the proposal that *CN/_V is a part of CON 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 preoralized and other kinds of stops contrast, preoralized segments are allowed *only* in prevocalic position. 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 – is derived under a channel bias account.

A second hardship becomes apparent when we consider the set of allophones produced by shielding in Karitiâna (Storto 1999). In languages like Karitiâna, where nasals are realized as medionasals between two oral vowels (/ama/ → [abmba]; though cf. Everett 2007 on variation between [bmb], [b], and [mb] in Karitiâna). An analysis in which shielding arises as a result of contextual neutralization would have to assume that medionasals were originally contrastive with plain nasals, and that complementary distribution between medionasals and other kinds of (partially) nasal segments arose through neutralization of consonantal and vocalic nasality contrasts, in different contexts. 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. More succinctly, the channel bias account of shielding must assume that all allophones produced by shielding were at one point contrastive. 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 prevocalic shielding example in (49), this is not true of the entire typology.

6 Extensions and Conclusions

In sum, this article 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: further contextual restrictions (and the lack thereof) on the distribution of shielding (Section 6.1); and support for the analysis beyond the typological survey discussed in Sections 2 and 3 (Section 6.2).

6.1 Further asymmetries in the typology of shielding

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. This prediction appears to hold: descriptions are often not clear about contextual limitations on contrasts in vocalic nasality, but in the five surveyed cases where it is extremely likely that contextual restrictions exist, shielding applies only in contexts where the vocalic nasality contrast is licensed (see Appendix B).

But there are other ways in which shielding does not track the distribution of vocalic nasality contrasts. In particular, whether or not shielding applies before a given oral vowel is not sensitive to whether or not that oral vowel has a nasal correspondent. In Karajá, for example, shielding applies before [ɪ], [ɨ], and [ʊ], even though nasal [ɪ̃], [ɨ̃], and [ʊ̃] do not exist (examples in Ribeiro 2001:79). More broadly, for 26/66 of the shielding languages surveyed, the oral vowel inventory is larger than the nasal vowel inventory (vowel inventories in Appendix B); none of the descriptions, however, mention that shielding fails to occur before oral vowels that lack nasal correspondents.

There are at least two potential explanations for this fact. The first is that predictable changes in the vowel quality of nasalized vowels (e.g. Beddor 1983) impact the distinctiveness of contrasts between those vowels and phonemically nasal vowels of different qualities. For example, Karajá [ɪ] contrasts not with nasal *[ɪ̃], but with nasal [ĩ]. It could be the case, however, that an allophonically nasalized [ɪ] is of similar quality to the phonemic [ĩ], thus rendering the contrast between them insufficiently distinct. Whether or not an explanation along these lines can account for the lack of sensitivity to vowel quality more generally is a question outside the scope of this article, as verifying this hypothesis would require careful study of allophonic nasalization in the 26 languages with fewer nasal than oral vowels. Another potential explanation for this fact is that the MINDIST constraints that motivate shielding can refer only to the presence vs. absence of a [±nasal] contrast: they evaluate only the perceptual distance between prototypical oral and nasal vowels (i.e. V vs. Ṽ), rather than each individual contrast between [i] and [ĩ], for example, or [a] and [ã]. If this latter explanation is the correct one, it would have substantial implications for the formalization and implementation of distinctiveness constraints: the claim that the relevant contrast is the one between a prototypical oral and a prototypical nasal vowel implies that distinctiveness constraints are evaluated at a higher level of abstraction than is currently assumed. As it is not clear which of these explanations (if either) is correct, I leave the questions raised here to future research.

6.2 Shielding outside of South America

As noted at the outset, the generalizations regarding the typology of shielding established in this article are based on a survey of South American languages. In order for the conclusions to hold universally, evidence that the 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 article, 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[23]), as

[23] Rice (1989:83) claims that all nasal vowels can be derived from V*n* 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

well as several others that appear to allow shielding without licensing a contrast in vocalic nasality. These latter cases are discussed below.

6.2.1 Prestopping in Australian languages

Prestopping, attested mainly in Australian and Austronesian languages, appears similar to shielding. Examples of prestopping from Arabana-Wangkangurru (Hercus 1972: 296) illustrate (54); where 'Common Australian' has an nasal, Arabana-Wangkangurru has a prestopped nasal.

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

	Common Australian	*Arabana-Wangkangurru*	*Gloss*
a.	tyi**n**a	thi**dn**a	'foot'
b.	ku**n**a	ku**dn**a	'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 *mu**l**u/mi**l**a*, for example, Arabana-Wangkangurru has *mi**dl**a*). This suggests that the alternations in (54) instantiate a process that is distinct from the class of shielding processes discussed above. As defined in Section 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 languages 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).

It is possible to differentiate a case of shielding from a case of prestopping 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 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, though see Steriade 1993b:343), 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.

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vowels, and changes in the Slavey dialect point to nasal vowels having acquired phonemic status (Rice 1989:83ff).

6.2.2 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.[24] Cho & Keating (2001) show that each of the Korean coronal stops – /n/, /t/, /t^h/, 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^h/ increase, the nasal energy associated with /n/ decreases, and so on (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.

6.3 Summary

The major finding of this article is that constraints on contrast are essential to the analysis of environmental shielding in South American languages. In Sections 2–4, I showed that the contrast-based analysis is capable of predicting three typological generalizations that characterize a large set of 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 parallel one another. 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 2008:32–35).

In section 5, I argued that the three conceivable alternative analyses of the shielding typology that do not explicitly refer to contrast all make unwanted predictions that are avoided under a contrast-based account. 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 the phonological grammar. The hope is that pursuing the areas for further research outlined in Sections 6.1 and 6.2 will serve to strengthen this result.

[24] 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).

Appendices for “Environmental shielding is contrast preservation”

Appendix A: list of shielding languages

Key for appendices A-C

Shaded = shielding occurs in this context

Not shaded = shielding not known to occur in this context

The language names provided in appendices A-C are those used by SAPhon.

Evidence = 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)

V-Ṽ?	(Evidence)	Shielding contexts			Language	Family	Source	Appendix B
		NV	VN]$_\sigma$	V]$_\sigma$N				
Yes	MP	■			Aché	Tupí	Roessler (2008)	#1, p. 34
Yes	MP	■			Aguaruna	Jivaroan	Overall (2007)	#2, p. 34
Yes	MP	■			Amahuaca	Panoan	Osborn (1948)	#3, p. 35
Yes	MP	■	■	■	Amarakaeri	Harakmbet	Tripp (1955)	#4, p. 35
Yes	MP	■	■		Amundava	Tupí	Sampaio (1998)	#5, p. 36
Yes	MP	■			Andoke	(Isolate)	Landaburu (2000a)	#6, p. 36
Yes	MP	■			Apiaká	Tupí	Padua (2007)	#7, p. 37
Yes	MP		■		Apinayé	Macro-Ge	Oliveira (2005)	#8, p. 37
Yes	–	■	■		Arára do Mato Grosso	Isolate	da Rocha D’Angelis (2010)	#9, p. 38
Yes	MP	■			Arikapú	Macro-Ge	Arikapú et al. (2010)	#10, p. 38
Yes	NVNE	■			Asurini do Xingú	Tupí	Pereira (2009)	#11, p. 39
Yes	MP	■			Avá-Canoeiro	Tupí	Borges (2006)	#12, p. 39
Yes	MP	■			Barí	Chibchan	Mogollón (2000)	#13, p. 40
Yes	MP	■			Chimila	Chibchan	Malone (2006, 2010)	#14, p. 40
Yes	MP	■			Chiriguano (Chané)	Tupí	Dietrich (1986)	#15, p. 41
Yes	MP	■			Chiriguano (Izoceño)	Tupí	Dietrich (1986)	#16, p. 41
Yes	MP		■		Dâw	Nadahup	Martins (2004)	#17, p. 42
Yes	NVNE	■			Epena	Choco	Harms (1984)	#18, p. 42
Yes	MP	■	■	■	Hup	Nadahup	Epps (2008)	#19, p. 43
Yes	MP	■			Jabutí	Macro-Ge	Ribeiro & van der Voort (2010)	#20, p. 43
Yes	NVNE	■	■		Júma	Tupí	Abrahamson & Abrahamson (1984)	#21, p. 44
Yes	NVNE	■			Kaapor	Tupí	Garcia Lopes (2009)	#22, p. 44
Yes	NVNE	■	■	■	Kaingang (São Paolo)	Macro-Ge	Cavalcante (1987)	#23, p. 45
Yes	NVNE	■	■		Kakua	Kakua-Nukak	Cathcart (1979)	#24, p. 45
Yes	NVNE	■			Karajá	Macro-Ge	Ribeiro (2012)	#25, p. 46

V-Ṽ?	(Evidence)	Shielding contexts			Language	Family	Source	Appendix B
		NV	VN]$_\sigma$	V]$_\sigma$N				
Yes	MP	■			Karapanã	Tucanoan	Metzger & Metzger (1973)	#26, p. 46
Yes	MP	■	■	■	Karitiâna	Tupí	Storto (1999), Everett (2007)	#27, p. 47
Yes	MP	■	■		Karo	Tupí	Gabas (1998)	#28, p. 47
Yes	NVNE	■			Kotiria	Tucanoan	Waltz & Waltz (1972)	#29, p. 48
Yes	MP		■		Krahô	Macro-Ge	Popjes & Popjes (2009)	#30, p. 48
Yes	NVNE	■	■	■	Krenak	Macro-Ge	Pessoa (2012)	#31, p. 49
Yes	NVNE	■	■		Krinkati-Timbira	Macro-Ge	Alves (2004)	#32, p. 49
Yes	MP	■			Kubeo	Tucanoan	Chacon (2012)	#33, p. 50
Yes	MP	■			Mako	Salivan	Labrada (2015)	#34, p. 50
Yes	MP	■			Makuráp	Tupí	Braga (1992)	#35, p. 51
Yes	MP		■		Mamaindé	Nambiquaran	Eberhard (2009)	#36, p. 51
Yes	NVNE	■			Maxakalí	Macro-Ge	Campos (2009)	#37, p. 52
Yes	NVNE	■			Mbyá	Tupí	Thomas (2014)	#38, p. 52
Yes	NVNE		■		Mebengokre	Macro-Ge	Salanova & Silva (2011)	#39, p. 53
Yes	MP		■		Mundurukú	Tupí	Picanço (2005)	#40, p. 53
Yes	MP	■			Myky	(Isolate)	Montserrat (2010)	#41, p. 54
Yes	MP		■		Nadëb	Nadahup	Barbosa (2005)	#42, p. 54
Yes	MP	■			Nhandeva	Tupí	Costa (2007)	#43, p. 55
Yes	MP	■	■	■	Nukak	Kakua-Nukak	Mahecha et al. (2000)	#44; p. 55
Yes	NVNE	■			Pai Tavytera	Tupí	Cardoso (2008)	#45, p. 56
Yes	MP	■			Piratapuyo	Tucanoan	Klumpp & Klumpp (1973)	#46, p. 56
Yes	MP	■			Poyanáwa	Panoan	De Paula (1992)	#47, p. 57
Yes	MP	■			Puinave	(Isolate)	Girón (2007)	#48, p. 57
Yes	MP	■			Secoya del Aguarico	Tucanoan	Johnson & Levinsohn (1990)	#49, p. 58
Yes	MP	■			Secoya del Putumayo	Tucanoan	Vallejos (2013)	#50, p. 58
Yes	NVNE	■			Sharanawa	Panoan	Pike & Scott (1962)	#51, p. 59
Yes	NVNE	■			Sirionó	Tupí	Gasparini (2012)	#52, p. 59
Yes	MP	■			Suyá	Macro-Ge	Guedes (1993)	#53, p. 60
Yes	MP	■			Tapayuna	Macro-Ge	Camargo (2010)	#54, p. 60
Yes	MP	■			Tenharim	Tupí	Sampaio (1998)	#55, p. 61
Yes	NVNE	■			Ticuna of San Martín de Amacayacu	Isolate	Montes Rodríguez (2005)	#56, p. 61
Yes	NVNE	■			Tupinambá	Tupí	Jensen (1984), Moore et al. (1993)	#57, p. 62
Yes	MP	■	■		Uru-Eu-Wau-Wau	Tupí	Sampaio (1998)	#58, p. 62

V-Ṽ?	**(Evidence)**	**Shielding contexts**			**Language**	**Family**	**Source**	**Appendix B**
		NV	VN]$_\sigma$	V]$_\sigma$N				
Yes	MP				Waimaha	Tucanoan	Stolte & Stolte (1976)	#59, p. 63
Yes	NVNE				Wari'	Chapakuran	Everett & Kern (1997)	#60, p. 63
Yes	NVNE				Wayampi (Alto Jarí)	Tupí	Jensen (1984)	#61, p. 64
Yes	NVNE				Wayampi (Ampari)	Tupí	Jensen (1984)	#62, p. 64
Yes	NVNE				Xavánte	Macro-Ge	Quintino (2000)	#63, p. 65
Yes	MP				Xetá	Tupí	Vasconcelos (2008)	#64, p. 65
Yes	–				Yagua	Peba-Yaguan	Peña (2009)	#65, p. 66
Yes	MP				Yuhup	Nadahup	Martins (2005)	#66, p. 66

#1: Aché (Tupí; Roessler 2008)

Shielding contexts	Prevocalic (NV → NDV, DV)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e o a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ õ ã
Stop inventory	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 síabas 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)

Shielding contexts	Prevocalic (NV → NDV, DV)
Variability?	Yes
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u a
Nasal vowel inventory	ĩ ɨ̃ ũ ã
Stop inventory	VOICELESS: p, t, ts, tʃ, k, ʔ NASAL: m, n

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

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)

Shielding contexts	Prevocalic (NV → NDV)
Variability?	None mentioned
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ï o a
Nasal vowel inventory	ĩ ï̃ õ ã
Stop inventory	VOICELESS: p, t, k, ʔ 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)

Shielding contexts	Prevocalic (NV → NDV) Coda $(VN]_\sigma \rightarrow VDN]_\sigma)$ Onset $(V]_\sigma N \rightarrow V]_\sigma DN)$
Variability?	None mentioned
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i u e o a
Nasal vowel inventory	ĩ ũ ẽ õ ã
Stop inventory	VOICELESS: p, t, k, ʔ 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)

Shielding contexts	Prevocalic (NV → NDV) Coda $(VN]_\sigma \rightarrow VDN]_\sigma)$
Variability?	Yes
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e o a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ õ ã
Stop inventory	VOICELESS: p, t, tʃ, k, k^w, ʔ NASAL: m, n, ɲ, ŋ, $ŋ^w$

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)

Shielding contexts	Prevocalic (NV → DV)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɯ u e ɤ o a ʌ ɒ
Nasal vowel inventory	ĩ ẽ ɤ̃ õ ã ɒ̃
Stop inventory	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)

Shielding contexts	Prevocalic (NV → NDV, DV)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e o a
Nasal vowel inventory	ĩ ũ ẽ ã
Stop inventory	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)

Shielding contexts	Coda $(VN]_\sigma \rightarrow VD]_\sigma)$
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e ɘ o ə ɛ ʌ ɔ a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ ɘ̃ õ ə̃
Stop inventory	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)

Shielding contexts	Prevocalic (NV → NDV, DV) Coda ($VN]_\sigma \rightarrow VDN]_\sigma$)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e ə o ɛ ɔ a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ õ ã
Stop inventory	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)

Shielding contexts	Prevocalic (NV → NDV, DV)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ü u ï ä e o a
Nasal vowel inventory	ĩ ũ ä̃ ẽ õ ã
Stop inventory	VOICELESS: p, t, k, ʔ 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)

Shielding contexts	Prevocalic (NV → NDV, DV)
Variability?	Yes
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ ã
Stop inventory	VOICELESS: p, t, tʃ, k, ʔ 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)

Shielding contexts	Prevocalic (NV → NDV, DV)
Variability?	Yes
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e o a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ õ ã
Stop inventory	VOICELESS: p, t, k, k^w 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 Tocatins 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)

Shielding contexts	Prevocalic (NV → NDV)
Variability?	Yes
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e o a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ õ ã
Stop inventory	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 libremente 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)

Shielding contexts	Prevocalic (NV → NDV)
Variability?	Yes
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i u e o a
Nasal vowel inventory	ĩ ũ ẽ õ ã
Stop inventory	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)

Shielding contexts	Prevocalic (NV → NDV)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	Probably not
Oral vowel inventory	i ɨ u e o a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ õ ã
Stop inventory	VOICELESS: p, t, k, k^w, 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)

Shielding contexts	Prevocalic (NV → NDV)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	Probably not
Oral vowel inventory	i ɨ u e o a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ õ ã
Stop inventory	VOICELESS: p, t, k, k^w, ʔ VOICED: g^w 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)

Shielding contexts	Coda (VN]$_\sigma$ → VDN]$_\sigma$)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɯ u e ɤ o ɛ ɔ a
Nasal vowel inventory	ĩ ɯ̃ ũ ɛ̃ ɔ̃ ã
Stop inventory	VOICELESS: p, t, c, k, ʔ VOICED: b, d, ɟ, g NASAL: m, n, ɲ, ŋ GLOTTALIZED NASAL: $m^ʔ$, $n^ʔ$, $ɲ^ʔ$

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)

Shielding contexts	Prevocalic (NV → NDV, DV)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e ə o a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ ə̃ õ ã
Stop inventory	VL. ASPIRATED: p^h, t^h, k^h 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)

Shielding contexts	Prevocalic (NV → NDV) Coda $(VN]_\sigma \rightarrow VDN]_\sigma$ Onset $(V]_\sigma N \rightarrow V]_\sigma D$, $V]_\sigma DND)$
Variability?	None mentioned
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e ə o æ a ɔ
Nasal vowel inventory	ĩ ɨ̃ ũ æ̃ ã ɔ̃
Stop inventory	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 ([ⁿdûː] 'grandchild', p. 54) and coda ([tôdⁿ] '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)

Shielding contexts	Prevocalic (NV → DV)
Variability?	Yes
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ʉ u ə ɛ o a
Nasal vowel inventory	ĩ ɛ̃ õ ã
Stop inventory	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)

Shielding contexts	Prevocalic (NV → NDV) Coda ($(VN]_\sigma \rightarrow VDN]_\sigma)$)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e o a
Nasal vowel inventory	ĩ ũ ẽ õ ã
Stop inventory	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 DNs 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)

Shielding contexts	Prevocalic (NV → NDV)
Variability?	Yes
Contextual restrictions on V–Ṽ?	Probably
Oral vowel inventory	i ɨ u e o a
Nasal vowel inventory	ĩ ũ ẽ õ ã
Stop inventory	VOICELESS: p, t, k, k^w NASAL: m, n, ŋ, $ŋ^w$

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 Paolo (Macro-Ge; Cavalcante 1987)

Shielding contexts	Prevocalic (NV → NDV) Coda ($VN]_\sigma \rightarrow VDN]_\sigma$) Onset ($V]_\sigma \rightarrow V]_\sigma DN$)
Variability?	Yes
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e ə o ɛ ɔ a
Nasal vowel inventory	ĩ ə̃ õ ɛ̃
Stop inventory	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 consonante nasal e uma vogal oral)."*

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

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

Shielding contexts	Prevocalic (NV → NDV, DV) Coda ($VN]_\sigma \rightarrow VDN]_\sigma$)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ e o a
Nasal vowel inventory	ĩ ɨ̃ ẽ õ ã
Stop inventory	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)

Shielding contexts	Prevocalic (NV → DV)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ̞ u ɪ ɨ ʊ e ɘ o ɛ (ə) ɔ a
Nasal vowel inventory	ĩ ə̃ õ ã
Stop inventory	VOICELESS: (tʃ), k VOICED/NASAL: b/m, d/n, (dʒ) IMPLOSIVE: ɗ

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)

Shielding contexts	Prevocalic (NV → NDV, DV)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e o a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ õ ã
Stop inventory	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: Karitiâna (Tupí; Storto 1999, Everett 2007)

Shielding contexts	Prevocalic (NV → NDV) Coda $(VN]_\sigma \rightarrow VDN]_\sigma)$ Onset $(V]_\sigma \rightarrow V]_\sigma DN)$
Variability?	Yes
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ï u / e ë o / ɛ̈ / ɛ ʌ ɔ / a iː ïː uː / eː ëː oː / ɛ̈ː / ɛː ʌː ɔː / aː
Nasal vowel inventory	ĩ ɨ̃ / ẽ õ / ã ĩː ɨ̃ː / ẽː õː / ãː
Stop inventory	VOICELESS: p, t, k NASAL: m, n, ň, ŋ

The distribution of allophones, according to Storto (1999:25ff), is: N → ND / Ṽ_ V, #_ V (older speakers only); N → DN / V_Ṽ, 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)

Shielding contexts	Prevocalic (NV → NDV) Coda $(VN]_\sigma \rightarrow VDN]_\sigma)$
Variability?	None mentioned
Contextual restrictions on V–Ṽ?	Probably
Oral vowel inventory	i ɨ u / e ə o / a
Nasal vowel inventory	ĩ / ẽ õ / ã
Stop inventory	VOICELESS: p, t, c, k, ʔ 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)

Shielding contexts	Prevocalic (NV $\rightarrow$ DV)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e o a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ õ ã
Stop inventory	VL. ASPIRATED: p, t, k VL. UNASPIRATED: p^h, t^h, k^h VOICED/NASAL: b/m, d/n, g/ŋ

Regarding shielding: Ns are only realized as Ds when both surrounding vowels are oral; /wãhãŋa/, for example, is realized as [wãhãŋa]. 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 simitría dentro de las oclusivas y continuas con sus variantes nasales."*

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

Shielding contexts	Coda ($VN]_\sigma \rightarrow VDN]_\sigma$)
Variability?	None mentioned
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ï u e ë o ɛ ɛ̈ ɔ a
Nasal vowel inventory	ĩ ḯ ũ ẽ ë̃ õ ɛ̃ ɛ̈̃ ɔ̃ ã
Stop inventory	VOICELESS: p, t, k NASAL: m, n, ŋ

A few details about shielding: the only restriction on the distribution of DNs 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)

Shielding contexts	Prevocalic (NV → NDV) Coda ($VN]_\sigma \rightarrow VDN]_\sigma$) Onset ($V]_\sigma N \rightarrow V]_\sigma DN$)
Variability?	Yes
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u ɛ ə o a
Nasal vowel inventory	ĩ ũ ɛ̃ õ ɜ̃
Stop inventory	VOICELESS: p, t, tʃ, k, ʔ VD. NASAL: m, n, ɲ, ŋ VL. NASAL: m̥, n̥, ɲ̥, ŋ̥

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 sílibas 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 $VN]_\sigma$ context, when shielding fails to apply, the vowel is nasalized (see Pessoa pp. 176ff).

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

Shielding contexts	Prevocalic (NV → NTV) Coda ($VN]_\sigma \rightarrow VDN]_\sigma$)
Variability?	Yes
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e ə o ɛ ɜ ɔ a
Nasal vowel inventory	ĩ ɨ̃ ũ ɛ̃ ɔ̃ ã
Stop inventory	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)

Shielding contexts	Prevocalic (NV → DV)
Variability?	None mentioned
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e o a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ õ ã
Stop inventory	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)

Shielding contexts	Prevocalic (NV → DV)
Variability?	None mentioned
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e ə o a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ õ ã
Stop inventory	ASPIRATED: p^h, t^h VOICELESS: p, t, k, k^w, 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)

Shielding contexts	Prevocalic (NV → NDV, DV)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ e o a
Nasal vowel inventory	ĩ ɨ̃ ẽ õ ã
Stop inventory	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)

Shielding contexts	Coda ($VN]_\sigma \rightarrow VDN]_\sigma$)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i u e o a DIPTHTHONGS: iu, ei, eu, ai, au
Nasal vowel inventory	ĩ ũ ẽ õ ã DIPTHTHONGS: ĩũ, ẽĩ, ẽũ, ãĩ, ãũ
Stop inventory	VL. UNASPIRATED: p, t, k, ʔ VL. ASPIRATED: p^h, t^h, k^h NASAL: m, n

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}m] after oral diphthongs with round vowels (/au/, /eu/); [^{g}ŋ] after the high front vowel (/i/); and [^{d}n] 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 dipththongs. These are however being lost in younger generations.

#37: Maxakalí (Macro-Ge; Campos 2009)

Shielding contexts	Prevocalic (NV → NDV, DV)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɯ e o a
Nasal vowel inventory	ĩ ɯ̃ ẽ õ ã
Stop inventory	VOICELESS: p, t, c, k, ʔ NASAL: m, n, ɲ, ŋ

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

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

Shielding contexts	Prevocalic (NV → NDV)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e o a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ õ ã
Stop inventory	VOICELESS: p, t, tʃ, k, k^w, ʔ NASAL: m, n, ɲ, ŋ, $ŋ^w$

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)

Shielding contexts	Coda ($VN]_\sigma \rightarrow VDN]_\sigma$)
Variability?	None mentioned
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɯ u e ɤ o ɛ ʌ ɔ a
Nasal vowel inventory	ĩ ɯ̃ ũ ẽ õ ã
Stop inventory	VOICELESS: p, t, tʃ, k, ʔ VOICED: b, d, dʒ, g NASAL: m, n, ɲ, ŋ

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)

Shielding contexts	Coda ($VN]_\sigma \rightarrow VDN]_\sigma$)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i e ə o a
Nasal vowel inventory	ĩ ẽ ə̃ õ ã
Stop inventory	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)

Shielding contexts	Prevocalic (NV → NDV)
Variability?	Yes
Contextual restrictions on V–Ṽ?	Probably
Oral vowel inventory	i y u / e ə o / a ; iː yː uː / eː əː oː / aː
Nasal vowel inventory	ĩ ỹ ũ / ẽ õ / ã ; ĩː ỹː ũː / ẽː ə̃ː õː / ãː
Stop inventory	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)

Shielding contexts	Coda $(VN]_\sigma \rightarrow VDN]_\sigma)$
Variability?	None discussed
Contextual restrictions on V–Ṽ?	Probably
Oral vowel inventory	i ɨ u / e ə o / ɛ ʌ ɔ / a ; iː ɨː uː / eː əː oː / ɛː ʌː ɔː / aː
Nasal vowel inventory	ĩ ɨ̃ ũ / ɛ̃ ʌ̃ ɔ̃ / ã ; ĩː ɨ̃ː ũː / ɛ̃ː ʌ̃ː ɔ̃ː / ãː
Stop inventory	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. /wɔjaˈpəm/ → [wɔjaˈpəᵇm], 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)

Shielding contexts	Prevocalic (NV → NDV)
Variability?	Yes
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u ɛ ɔ a
Nasal vowel inventory	ĩ ɨ̃ ũ ɛ̃ ɔ̃ ã
Stop inventory	VOICELESS: p, t, ts, tʃ, k, kʷ, 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)

Shielding contexts	Prevocalic (NV → DV) Coda (VN]$_\sigma$ → VDN]$_\sigma$) Onset (V]$_\sigma$ → VD]$_\sigma$, VDN]$_\sigma$)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u ɛ ʌ a
Nasal vowel inventory	ĩ ɨ̃ ũ ɛ̃ ʌ̃ ã
Stop inventory	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)

Shielding contexts	Prevocalic (NV → NDV, DV)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e o a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ õ ã
Stop inventory	VOICELESS: p, t, k, kʷ NASAL: m, n, ɲ, ŋ, ŋʷ

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)

Shielding contexts	Prevocalic (NV → DV)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e o a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ õ ã
Stop inventory	VOICELESS: p, t, k, ʔ 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)

Shielding contexts	Prevocalic (NV → DV)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u a
Nasal vowel inventory	ĩ ɨ̃ ũ ã
Stop inventory	VOICELESS: p, t, k VOICED/NASAL: b/m, d/n

Regarding the analysis of consonantal alternations: De Paula treats the oral allophones as underlying (thef 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)

Shielding contexts	Prevocalic (NV → DV, NDV
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɯ u e ɤ o a
Nasal vowel inventory	ĩ ɤ̃ õ ã
Stop inventory	VOICELESS: p, t, k, ʔ 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)

Shielding contexts	Prevocalic (NV → DV)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e o a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ õ ã
Stop inventory	VOICELESS: p, t, k, kʷ, ʔ 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)

Shielding contexts	Prevocalic (NV → DV)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e o a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ õ ã
Stop inventory	VOICELESS: p, t, k, kʷ, ʔ 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)

Shielding contexts	Prevocalic (NV → NDV)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ï o a
Nasal vowel inventory	ĩ ï̃ õ ã
Stop inventory	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)

Shielding contexts	Prevocalic (NV → NDV)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e o a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ õ ã
Stop inventory	VOICELESS: t, k, k^j 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, Ṽ_V, and N → N / #_V, V_Ṽ, V_V. There are also postoralized palatal and velar allophones ([ɲdʒ]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)

Shielding contexts	Prevocalic (NV → NDV, DV)
Variability?	Yes
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e o ɛ ɔ a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ õ ã
Stop inventory	VOICELESS: p, t, č, k NASAL: m, n, ñ, ŋ

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 ([nǰ] and [nč]) are treated as allophones of plain affricates. However, they appear to be in complementary distribution with the palatal nasal [ɲ], and [nǰ] appears to be in free variation with [ǰ]. Both appear before oral vowels only; [nǰ] and its variant [ǰ] can appear word-initially while [nč] cannot. See Guedes p. 54 for more details.

#54: Tapayuna (Macro-Ge; Camargo 2010)

Shielding contexts	Prevocalic (NV → NDV)
Variability?	Yes
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e ə o ɛ ʌ ɔ a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ õ ɐ̃
Stop inventory	VOICELESS: t, ʈ, 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)

Shielding contexts	Prevocalic (NV → NDV)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e o a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ õ ã
Stop inventory	VOICELESS: p, t, tʃ, k, k^w, ʔ NASAL: m, n, ɲ, ŋ, $ŋ^w$

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)

Shielding contexts	Prevocalic (NV → DV)
Variability?	Yes
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɯ u / iː ɯː uː e o / eː oː a / aː
Nasal vowel inventory	ĩ ɯ̃ ũ / ĩː ɯ̃ː ũː ẽ õ / ẽː õː ã / ãː
Stop inventory	VOICELESS: p, t, tʃ, k, k^w, ʔ VOICED/NASAL: b/m, d/n, ɟ/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)

Shielding contexts	Prevocalic (NV → NDV)
Variability?	Yes
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e o a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ õ ã
Stop inventory	VOICELESS: p, t, k, ʔ 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)

Shielding contexts	Prevocalic (NV → NDV) Coda $(VN]_\sigma \rightarrow VDN]_\sigma)$
Variability?	Yes
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e o a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ õ ã
Stop inventory	VOICELESS: p, t, tʃ, k, kʷ, ʔ NASAL: m, n, ɲ, ŋ, ŋʷ

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 DNs. 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)

Shielding contexts	Prevocalic (NV → NDV, DV)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e o a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ õ ã
Stop inventory	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)

Shielding contexts	Prevocalic (NV → NDV)
Variability?	Yes
Contextual restrictions on V–Ṽ?	Probably
Oral vowel inventory	i y u e o a
Nasal vowel inventory	FALLING DIPHTHONGS: $\tilde{e}^{\tilde{\imath}}$, $\tilde{a}^{\tilde{\imath}}$, $\tilde{o}^{\tilde{\imath}}$, $y^{\tilde{\imath}}$ RISING DIPHTHONGS: $\tilde{\imath}^{\tilde{o}}$, $\tilde{e}^{\tilde{o}}$, $\tilde{a}^{\tilde{o}}$, $\tilde{o}^{\tilde{o}}$
Stop inventory	VOICELESS: p, t, tʃ, k, k^w 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)

Shielding contexts	Prevocalic (NV → NDV)
Variability?	Yes
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e o a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ ã
Stop inventory	VOICELESS: p, t, k, kʷ, ʔ NASAL: m, n, ŋ, ŋʷ

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. [pɨãpè], 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)

Shielding contexts	Prevocalic (NV → NDV)
Variability?	Yes
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e o a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ ã
Stop inventory	VOICELESS: p, t, k, kʷ, ʔ NASAL: m, n, ŋ, ŋʷ

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. [pɨãpè], 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)

Shielding contexts	Prevocalic (NV → DV)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e ɤ o ɛ ɔ a
Nasal vowel inventory	i e o ɛ a
Stop inventory	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)

Shielding contexts	Prevocalic (NV → NDV)
Variability?	Yes
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e o a
Nasal vowel inventory	ĩ ɨ̃ ẽ õ ã
Stop inventory	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)

Shielding contexts	Prevocalic (NV → NDV)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɨ u e o a
Nasal vowel inventory	ĩ ɨ̃ ũ ẽ õ ã
Stop inventory	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)

Shielding contexts	Prevocalic (NV → DV) Coda ($VN]_\sigma \to VDN]_\sigma$, $VD]_\sigma$) Onset ($V]_\sigma \to V]_\sigma DN$)
Variability?	None discussed
Contextual restrictions on V–Ṽ?	None obvious
Oral vowel inventory	i ɯ u e ɤ o ɛ ɔ a
Nasal vowel inventory	ĩ ɯ̃ ũ ɛ̃ ɔ̃ ã
Stop inventory	VOICELESS: p, t, c, k, ʔ VOICELESS GLOTTALIZED: cˀ, kˀ VOICED/NASAL: b/bm/m, d/dn/n, ɟ/ɟɲ/ɲ, g/gŋ/ŋ GLOT. VOICED/NAS: bˀ/mˀ, dˀ/nˀ, ɟˀ/ɲˀ, gˀ/ŋˀ

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.

Appendix C: list of non-shielding languages

No.	V-Ṽ?	Evidence	Language	Family	Source	Notes?
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)	
Y6	Yes	MP	Awa-Cuaiquier	Barbacoan	Calvache (2000)	
Y7	Yes	NVNE	Ayoreo	Zamucoan	Bertinetto (2009)	
Y8	Yes	MP	Bakairí (Eastern)	Carib	Meira (2005)	
Y9	Yes	MP	Bakairí (Western)	Carib	Meira (2005)	
Y10	Yes	MP	Barasana-Eduria	Tucanoan	Gomez & Kenstowicz (2000)	[N∼D] due to nas. harm.
Y11	Yes	MP	Baré	Arawak	Aikhenvald (1995)	
Y12	Yes	NVNE	Bésiro	Macro-Ge	Sans (2010)	[N∼D] due to nas. harm.
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)	[N∼D] due to nas. harm.
Y19	Yes	–	Emberá-Baudó	Choco	Adelaar & Muysken (2004)	
Y20	Yes	MP	Emberá-Catío	Choco	Mortensen (1994)	[N∼D] due to nas. harm.
Y21	Yes	NVNE	Emberá-Chamí	Choco	Aguirre-Licht (1998)	
Y22	Yes	NVNE	Emerillon	Tupí	Rose (2003)	[N∼D] due to nas. harm.
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)	[N∼D] due to nas. harm.
Y32	Yes	MP	Kamayura	Tupí	Seki (2000)	

No.	V-Ṽ?	Evidence	Language	Family	Source	Notes?
Y33	Yes	MP	Kanoé	(Isolate)	Bacelar (2004)	
Y34	Yes	MP	Katukína (Panoan)	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)	[N∼D] due to nas. harm.
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)	[N∼D] due to nas. harm.
Y54	Yes	NVNE	Parkateje	Macro-Ge	de Nazaré de Oliveira (2003)	
Y55	Yes	MP	Pisamira	Tucanoan	de Pérez (2000)	[N∼D] due to nas. harm.
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)	[N∼D] due to nas. harm.
Y63	Yes	NVNE	Suruí	Tupí	van der Meer (1982)	
Y64	Yes	NVNE	Tanimuca-Retuarã	Tucanoan	Ardila (2000)	
Y65	Yes	MP	Tapieté	Tupí	González (2005)	[N∼D] due to nas. harm.
Y66	Yes	NVNE	Tapirapé	Tupí	Praça (2007)	
Y67	Yes	NVNE	Tariana	Arawak	Aikhenvald (2003)	[N∼D] due to nas. harm.

No.	V-Ṽ?	Evidence	Language	Family	Source	Notes?
Y68	Yes	MP	Tatuyo	Tucanoan	Whisler & Whisler (1976)	[N∼D] due to nas. harm.
Y69	Yes	NVNE	Tsáfiki	Barbacoan	Moore (1962)	
Y70	Yes	NVNE	Tsimané	Mosetenan	Sakel (2011)	
Y71	Yes	MP	Tucano	Tucanoan	Welch & West (2000)	[N∼D] due to nas. harm.
Y72	Yes	MP	Tuyuca	Tucanoan	Barnes & Silzer (1976)	[N∼D] due to nas. harm.
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)	[N∼D] due to nas. harm.
Y77	Yes	NVNE	Xerénte	Macro-Ge	de Souza (2008b)	[N∼D] due to nas. harm.
Y78	Yes	NVNE	Xokleng	Macro-Ge	Gakran (2005)	
Y79	Yes	NVNE	Yaminawa	Panoan	Faust & Loos (2002)	[N∼D] due to nas. harm.
Y80	Yes	MP	Yanomámi	Yanomam	Migliazza (1972)	[N∼D] due to nas. harm.
Y81	Yes	NVNE	Yora	Panoan	Anonymous (2001)	[N∼D] due to nas. harm.
Y82	Yes	NVNE	Yurutí	Tucanoan	Kinch & Kinch (2000)	[N∼D] due to nas. harm.
Y83	Yes	NVNE	Zo'é	Tupí	Cabral (2009)	[N∼D] due to nas. harm.
N1	No		Abipon	Guaicuru	Najilis (1966)	
N2	No		Achagua	Arawak	Wilson & Levinsohn (1992)	
N3	No		Akurio	Carib	Meira (1998)	
N4	No		Alacalufe (Central)	Alacufan	Barros (2005)	
N5	No		Alacalufe (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)	
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)	

No.	V-Ṽ?	Evidence	Language	Family	Source	Notes?
N20	No		Bolivian Quechua (Northern and Southern)	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)	
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)	See §2.1
N51	No		Ese Ejja	Tacanan	Vuillermet (2012)	See §2.1
N52	No		Ferreñafe Quechua	Quechua	Taylor (1982)	
N53	No		Guajajára	Tupí	Bendor-Samuel (1972)	
N54	No		Guambiano	Barbacoan	Branks & Branks (1973)	

No.	V-Ṽ?	Evidence	Language	Family	Source	Notes?
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)	
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 dialect)	(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)	
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)	

No.	V-Ṽ?	Evidence	Language	Family	Source	Notes?
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)	
N104	No		Nomatsigenga	Arawak	Shaver (1996)	
N105	No		North Junín Quechua (San Pedro de Cajas)	Quechua	Adelaar (1977)	
N106	No		North 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		Puri	Macro-Ge	Neto (2007)	
N123	No		Resígaro	Arawak	Allin (1976)	
N124	No		Reyesano	Tacanan	Guillaume (2012)	

No.	V-Ṽ?	Evidence	Language	Family	Source	Notes?
N125	No		Sabanê	Nambiquaran	Antunes de Araujo (2004)	
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 & Wrisley (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 dialect)	Chibchan	Headland (1997)	
N147	No		Umotína	Macro-Ge	Lima (1995)	See §2.1
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)	

No.	V-Ṽ?	Evidence	Language	Family	Source	Notes?
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	Yanomam	Aikhenvald & Dixon (1999)	
N166	No		Yavitero	Arawak	Mosonyi et al. (2000)	
N167	No		Yawalapití	Arawak	Mujica (1992)	
N168	No		Yawanawa	Panoan	Cruvinel (2009)	
N169	No		Yekwana	Carib	Cáceres (2007)	
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)	

Appendices for "Environmental shielding is contrast preservation"

Appendix D: summary of vowel neutralization survey

Key for appendix D

Shaded = contrasts in vocalic nasality neutralized in this context

Not shaded = contrasts in vocalic nasality not known to be neutralized in this context

?? = author claims that contrasts in vocalic nasality are neutralized before nasals, but provides only examples of $VN]_\sigma$.

– = independent phonotactic restrictions (i.e. no coda nasals) make this context impossible to examine.

The language names provided in appendix D are those provided by Ethnologue. Where they differ significantly, language names provided by the cited sources are included in parentheses.

No.	Restrictions?	Neut. Contexts			Language	Family	Source
		NV	$VN]_\sigma$	$V]_\sigma N$			
Y1	Yes	(shaded)			Aceh	Austronesian	Durie (1985)
Y2	Yes	(shaded)			Drubea (Ndumbea)	Austronesian	Gordon & Maddieson (1999)
Y3	Yes	(shaded)			Éwé	Niger-Congo	Westermann (1930)
Y4	Yes		(shaded)		Gbaya-Bossangoa (Gbeya)	Niger-Congo	Samarin (1966)
Y5	Yes		(shaded)	??	Hindi	Indo-European	Ohala (1975)
Y6	Yes	(shaded)			Ho-Chunk (Winnebago)	Siouan	Miner (1989)
Y7	Yes	(shaded)	(shaded)	(shaded)	Khana	Niger-Congo	Ikoro (1996)
Y8	Yes	(shaded)	(shaded)		Kiowa	Kiowa-Tanoan	Watkins (1984)
Y9	Yes	(shaded)			Lakota	Siouan	Rood & Taylor (1996)
Y10	Yes	(shaded)			Mazatec, Jalapa de Díaz	Otomanguean	Silverman et al. 1995
Y11	Yes	(shaded)	(shaded)	??	Mbay	Nilo-Saharan	Keegan (1997)
Y12	Yes	(shaded)	–	(shaded)	Mixtec, Atatláhuca	Otomanguean	Alexander (1980)
Y13	Yes	(shaded)	–		Mixtec, Coatzospan	Otomanguean	Gerfen (1999)
Y14	Yes	(shaded)	–	–	Mbembe	Niger-Congo	Kemmermann (2014)
Y15	Yes	(shaded)	–	–	Me'phaa, Malinaltepec (Tlanpaneca)	Otomanguean	Suárez (1983)
Y16	Yes	(shaded)			Navaho	Athabaskan	Sapir & Hoijer (1967)
Y17	Yes	(shaded)	(shaded)	(shaded)	Niellim (Lua)	Niger-Congo	Boyeldieu (1985)
Y18	Yes	(shaded)	–		Nupe-Nupe-Tako	Niger-Congo	Dunstan (1969)
Y19	Yes	(shaded)	–		Oka-Akoko	Niger-Congo	Oyebade (1985)
Y20	Yes	(shaded)			Paicî	Austronesian	Gordon & Maddieson (2004)
Y21	Yes	(shaded)	–		Sanumá	Yanomaman	Borgman (1990)
Y22	Yes	(shaded)	(shaded)	(shaded)	Saramaccan	Creole, English based	McWhorter & Good (2012)
Y23	Yes		(shaded)		Saint Lucian Creole French	Creole, French based	Carrington (1984)

No.	Restrictions?	Neut. Contexts			Language	Family	Source
		NV	VN$]_\sigma$	V$]_\sigma$N			
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-Congo	Welmers (1976)
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)
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)

No.	Restrictions?	Neut. Contexts			Language	Family	Source
		NV	VN]$_\sigma$	V]$_\sigma$N			
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)
N41	None discussed				Ngbaka	Niger-Congo	Thomas (1963)
N42	None discussed				Nishnaabemwin	Algonquian	Valentine (2001)
N43	None discussed				Ojibwa, 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				Popoloca, 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	Hoijer & Dozier (1949)
N59	None discussed				Tiwa, Northern, Taos	Kiowa-Tanoan	Trager (1946)

No.	Restrictions?	Neut. Contexts			Language	Family	Source
		NV	$VN]_\sigma$	$V]_\sigma N$			
N60	None discussed				Tsimané (Mosetén)	Mosetenan	Sakel (2004)
N61	None discussed				Tuscarora	Iroquoian	Mithun Williams (1976)
N62	None discussed				Vute	Niger-Congo	Guarisma (1978)
N63	None discussed				Wampanoag (Massachusett)	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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