Chapter 2

A CROSS-LINGUISTIC TYPOLOGY OF NASAL HARMONY

In this chapter I develop a description and analysis of a cross-linguistic typology of nasal harmony, focusing on variability in the set of segments undergoing nasalization and in those that block or behave transparent to nasal spreading. Across these variables, I propose to unify our understanding of nasal harmony as conforming to one basic type of pattern. As the basis for this study, I have compiled a database of nasal harmony systems, which comprises descriptions from over 75 languages. Each language entry includes information about the inventory of segments, the set of segments undergoing nasalization, and any blocking or transparent segments. The cross-linguistic generalizations established in this research define the facts to be explained by the analysis. These facts are summarized in this chapter and a condensed version of the database itself is appended.

Two central theoretical points illuminate the unified account of nasal harmony. First, building on previous studies of the compatibility of nasalization with different segments, it is argued that cross-linguistic variation in nasal harmony is limited by a phonetically-grounded hierarchy which ranks segments in terms of their harmonicity under nasalization. After nasal stops, vowels are ranked as most compatible with nasalization in this hierarchy. Obstruents, on the other hand, are ranked as least compatible. The nasalization hierarchy is implicational in the sense that if a segment undergoes nasal spreading, all segments more compatible with nasalization will also be targetted. The hierarchy is analyzed in an optimality-theoretic framework as composed of intrinsically-ranked nasal feature cooccurrence constraints. Variation in the set of undergoing segments is then derived by ranking the nasal spreading constraint at different points in the constraint hierarchy, generating just the variability which is attested.

The second point concerns transparent segments in nasal harmony. To begin, there appears to be a gap in the set of variants predicted by the implicational hierarchy: there is no language in which all segments are nasalized in nasal harmony; some obstruents resist nasalization (see second row in (1a)). Also, as diagrammed in (1a), the typology of nasal harmony outlined here finds that while the majority of segments either block spreading or become nasalized, some obstruents (typically voiceless ones) behave differently, either blocking or behaving transparent. When transparent, obstruents remain oral but permit the continuation of nasal spreading. These two observations fit together like pieces of a puzzle: systems with a set of transparent segments form the *complement* to those with blocking segments. To explain this complementarity, it is proposed that systems with transparent obstruents fill the gap of a system targetting all segments, i.e. transparent obstruents should be understood as belonging to the set of segments *undergoing* nasal harmony, as outlined in (1b).

(1) a. Observed possible patterning of segments in nasal harmony:

	Vocoids	Liquids	Obstruents	
Blockers (block spreading)	✓	✓	✓	
Targets (become nasalized)	✓	✓	✓	✗
Transparent segments (remain oral, do not block)	✗	✗	✗	✓

b. Proposed analysis of segmental behavior in nasal harmony:

	Vocoids	Liquids	Obstruents
Blockers (block spreading)	✓	✓	✓
Targets (undergo [nasal] spreading)	✓	✓	✓

Factorial ranking in the optimality-theoretic framework (Prince and Smolensky (1993) predicts the possibility of a grammar in which nasal spreading would be ranked high enough to derive even nasalized segments at the extreme of incompatibility. With this move, nasal harmony is unified into a basic pattern in which segments simply either undergo or block, and all possible variations produced by different rankings are attested. In this unified analysis of the typology, transparency arises as a resolution for an incompatible segment that undergoes nasal spreading.

In further support of this claim, it is observed that there is an implication in the occurrence of voiceless transparent obstruents and the behavior of other segments. When voiceless obstruents behave transparent to nasal harmony, all other classes of segments undergo nasalization, that is, they exhibit a nasal alternant in nasal contexts. Voiceless obstruents never behave transparent when segments more compatible with nasalization block nasal spreading. As I will show, this asymmetry suggests that all segments, including obstruents, are targetted by nasalization in these languages. Importantly, the finding that descriptively transparent segments pattern with undergoers lends support to phonological studies arguing that spreading or sharing of structure can never skip an intervening segment, a result derived by claiming that a gapped configuration in feature linking is universally ill-formed (Ní Chiosáin and Padgett 1997; cf. Gafos 1996 on Articulatory Locality; for foundation, see analyses of Ní Chiosáin and Padgett 1993; McCarthy 1994; Flemming 1995b; Padgett 1995a; also Allen 1951; Stampe 1979). The surface-transparent resolution for transparent segments, while still maintaining locality, is worked out in chapter 3.

This chapter is organized as follows. First in section 2.1 I present the descriptive facts, exhibiting the hierarchical cross-linguistic variation in nasal harmony and summarizing the key generalizations established by the nasal harmony database. Next, in 2.2, I develop an analysis of the typology, using an intrinsically-ranked hierarchy of nasalized segment constraints. Ranking the nasal spreading constraint at all possible points in this hierarchy proves to derive precisely the typology that is required. In section 2.3, I adduce further evidence for the nasalization hierarchy by exploring examples in which separate constraints are ranked at different points in the fixed hierarchy. Finally, in the appendix in 2.4 I present a condensed version of the nasal harmony database and discuss some of the findings from this survey in more detail.

2.1 Hierarchical variation in nasal harmony

The behavior of segments in nasal harmony falls into three descriptive categories: *target segments* are those that undergo nasal spread, *blocking segments* remain oral and block nasal spreading, and *transparent segments* remain oral but do not block nasalization of subsequent segments. In this section I show that languages which divide their segments exhaustively into blockers and targets exhibit limited variation in the content of these sets. One limitation is that the set of blockers always includes obstruent stops. This at first appears to deny the prediction that all possible variants in the typology should be attested (formalized in Optimality Theory as the factorial typology hypothesis; Prince and Smolensky 1993) — the expectation is that there should be a language in which obstruent stops belong to the set of targets and undergo nasal spreading. A central insight in this examination of the typology is that systems with transparency form the *complement* to those just mentioned by including all consonants, including obstruent stops, in the set of segments which nasalization spreads through, i.e. the set of segments that become nasalized or are ‘skipped’. This forms the basis for the argument that systems with blocking and systems with descriptively transparent segments are of one basic type in which all segments are grouped into either the set of blockers or the set of

targets; otherwise the complementary relationship between these systems would be accidental. Central to this claim is the idea that variation in nasal harmony must adhere to a hierarchy of segments.

As discussed in Walker (1995), previous surveys of nasalization (Schourup 1972; Piggott 1992; Cohn 1993c; cf. also Pulleyblank 1989) find that variation in the sets of supralaryngeal targets and blockers in nasal harmony obeys the implicational hierarchy in (2), where for each division, marked by a numeric label, all segments to the left will be targets, while those to the right will block.

(2) Implicational nasalization hierarchy:

① Vowels ② Glides ③ Liquids ④ Fricatives ⑤ Obstruent Stops ⑥
← high———*compatibility with nasalization*———low →

In previous work this hierarchy of segments has only been assumed to apply to systems with blocking, separating them from systems with transparency. However, I will propose that this basic hierarchy governs variation in all nasal harmony. The typology of variation that will be developed here posits all nasal harmony as strictly local, unifying the harmony systems exhibiting blocking with those with transparency. The claim underlying this proposal is that skipping of segments does not occur, so all non-participating segments are blockers. ‘Transparent’ segments, on the other hand, pattern with the set of targets in allowing nasalization to spread through them. In systems with no blockers but some descriptively transparent segments, all segments thus behave as undergoers, which will be another variation conforming to the hierarchy in (2).

I begin by exemplifying hierarchical variation in systems with a set of segments that block nasal spreading. Sundanese, a Malayo-Polynesian language spoken in Western Java, provides an example of the most limited nasal harmony, in which only vowels participate and the remaining supralaryngeals block (see (3)) (examples e, f, g, and h are due to Cohn 1990, all others are from Robins 1957). The consonantal inventory for Sundanese is as follows: [p, b, t, d, t͡ʃ, d͡ʒ, k, g, s, m, n, ɲ, ŋ, l, r, j, w, h, ʔ] (distribution of the glottal stop is not phonemic; Robins 1957). In Sundanese nasalization spreads rightward from a nasal stop. In these and subsequent examples nasalization is marked on segments with a tilde. In nasal contexts I show a tilde on the glottal segments [h] and [ʔ]. The status of glottals in nasal harmony will be addressed in section 2.2.3.

(3) Sundanese

a.	ɲãĩ̃ãn	‘to wet’
b.	kumãh̃ã	‘how?’
c.	bɤŋh̃ãr	‘to be rich’
d.	mĩʔ̃ãsih	‘to love’
e.	ŋãjak	‘to sift’
f.	mãwur	‘to spread’
g.	mõlohok	‘to stare’
h.	mãro	‘to halve’
i.	ŋũdag	‘to pursue’
j.	ŋãtur	‘to arrange’

The Johore dialect of Malay, another Malayo-Polynesian language, illustrates the second variation, in which glides also undergo a rightward spreading of nasality from a nasal consonant (Onn 1980). Liquids and obstruents block spreading. The Malay inventory contains the following consonants [p, b, t, d, t͡ʃ, d͡ʒ, k, g, s, m, n, ɲ, ŋ, l, r, j, w, h, ʔ] (glottal stop is again non-phonemic).

(4) Malay (Johore dialect)

a.	mĩnõm	‘to drink’
b.	baŋõn	‘to rise’
c.	mãʔ̃ãp	‘pardon’
d.	pənə̃ŋãh̃ãn	‘central focus’
e.	mãj̃ãŋ	‘stalk (palm)’
f.	mə̃nãw̃ãn	‘to capture’ (active)
g.	mə̃ratappi	‘to cause to cry’
h.	pəŋãw̃ãsan	‘supervision’
i.	mãkan	‘to eat’

Ijo, a Kwa language of Nigeria, is an example of the third variation, where liquids are added to the set of undergoing segments (Williamson 1965, 1969b, 1987). In this language, nasality spreads from a nasal consonant or nasal vowel. Unlike the rightward spread of the two previous examples, nasal spreading is leftward in Ijo. Examples of nasal harmony from the Central Ijo Kolokuma dialect are given in (5). The consonant inventory is as follows: [p, b, t, d, k, g, k͡p, g͡b, f, v, s, z, ɣ, m, n, ŋ, ɾ, l, j, w, h].

Nasalization of the flap is shown in examples (d-e). Williamson (1987: 401) notes that before a vowel [l] and [n] are in complementary distribution, [l] occuring before oral vowels and [n] before nasal. In nasal vocalic environments she posits /l/ as nasalizing to [n].

(5) Ijo (Kolokuma dialect)

a.	õmba	‘breath’
b.	ãnda	‘wrestle’
c.	w̃ãĩ	‘prepare sugarcane’
d.	j̃ãɾ̃ĩ	‘shake’
e.	sɔ̃ɾ̃ɔ̃	‘five’
f.	sãnlo	‘gills’
g.	izõŋgo	‘jug’
h.	abãmu	‘loft’
i.	otõŋgbolo	‘mosquito’
j.	tɔ̃nĩ	‘light (a lamp)’

The Applecross dialect of Scottish Gaelic, a Celtic language spoken in Scotland, illustrates the fourth variation in which nasalization carries through fricatives (Ternes 1973). Nasality spreads rightward from a stressed nasal vowel (usually in the initial syllable) until checked by an obstruent stop. It also nasalizes the onset of the syllable containing the stressed vowel, provided the onset is not an obstruent stop.[1] Examples are given in (6). Three vowel lengths are distinguished; one raised triangle marks half-long, two triangles mark long, and short vowels are unmarked. The inventory contains the following consonants: [p, p^h, b, b^h, t, t^h, d, d^h, t^j, t^{jh}, d^j, d^{jh}, k^j, k^{jh}, g^j, g^{jh}, k, k^h, g, g^h, f, v, s, ʃ, ç, ʝ, x, ɣ, m, n, n^j, ŋ, r, ʀ, l, l^j, ʟ, j, h] (voiced aspirated stops are used by conservative speakers only).

(6) Scottish Gaelic (Applecross dialect)

a.	/mã·har/	[mã·h̃ãr̃]	‘mother
b.	/tʲĩanu/	[tʲĩãnũ]	‘to do, to make’
c.	/frĩa·v/	[f̃r̃ĩã·ṽ]	‘root’ (plural)
d.	/ʃɛ̃nɛ·var/	[ʃ̃ɛ̃nɛ̃ṽãr̃]	‘grandmother’

[1] Ternes notes some complexities in relation to the mid-high vowels. These will be discussed in section 2.4.

e.	/ʟãːʝ/	[ʟ̃ãːʝ̃]	'hand'
f.	/ãhuç/	[ãh̃ũç̃]	'neck'
g.	/sŋãˑnʲdʲan/	[s̃ŋãˑnʲdʲan]	'thread'
h.	/tʰãhusk/	[tʰãh̃ũs̃k]	'senseless person, fool'
i.	/strãiˑɣ/	[st̃r̃ãĩˑɣ̃]	'string'
j.	/kʰɔ̃ispaxk/	[kʰɔ̃ĩs̃paxk]	'wasp'[2]

The above examples illustrate four hierarchical variations in the set of segments undergoing nasal harmony. In general terms, the hierarchy governing the variants has five segmental classes: Vowels, Glides, Liquids, Fricatives, and Obstruent Stops, where each variation in the set of participating segments corresponds to a step in the hierarchy (see (2)). Yet there is a further step at either end of the hierarchy which must also be considered. The remaining step at the left or top end corresponds to a variant in which all segments block nasal spreading. This will be a language with no nasal harmony, such as Spanish (Standard). At the opposite extreme there is a step corresponding to a variant targetting all segments. Yet there appears to be no surface-true example of this kind, which is unexpected given the assumption in Optimality Theory that all constraint rankings are possible. In fact, I claim that there are examples which could be reasonably slotted in this last category. I propose that nasal harmony in which no segments block nasal spreading and some obstruents behave transparent is an instance of this case. This kind of pattern occurs in Tuyuca.

Tuyuca is a Tucanoan language spoken in Colombia and Brazil (Barnes and Takagi de Silzer 1976; Barnes 1996).[3] Its inventory of consonants is as follows [p, b, t, d, k, g, m, n, ŋ, s, r, w, j, h] with nasal and voiced stops in complementary distribution in outputs, as defined by nasal harmony contexts (Barnes 1996: 33). Morphemes in Tuyuca are descriptively characterized as nasal or oral as a whole, as in (7). Within an oral morpheme, all segments are oral; in a nasal morpheme, all segments are nasal except for voiceless obstruents. In oral morphemes, all voiced stops are produced as oral obstruent stops and in the output of nasal morphemes, all voiced stops are fully nasal sonorant stops. Because nasality spreads to all nasalizable segments in a nasal morpheme, it is impossible to unambiguously pinpoint the segment from which nasal spreading originates. For ease of exposition, I will simply assume that nasality originates from a nasal vowel or stop in the first syllable in a nasal morpheme (Tuyuca vowels are [i, ɨ, u, e, a, o], each with a nasal counterpart).[4] In Tuyuca, spreading from the trigger segment is bidirectional, and it is not blocked by any segments within the morpheme. Voiceless obstruents are transparent to the nasal harmony in the sense that they always surface as oral and yet they do not prevent nasalization from spreading past them to other segments in a nasal morpheme. (Below I transcribe nasalized /j/ as [j̃]; Barnes (1996) transcribes this as [ɲ].)

(7) Tuyuca

Oral			Nasal		
a.	wáa	'to go'	n.	w̃ã́ã	'to illuminate'
b.	watɨ́	'dandruff'	o.	w̃ãtɨ̃́	'demon'
c.	hoó	'banana'	p.	h̃õṍ	'there'
d.	keeró	'lightning bug'	q.	k̃ẽẽr̃ṍ	'a dream'
e.	osó	'bat'	r.	j̃õsṍ	'bird'
f.	botá	'post'	s.	ẽmṍ	'howler monkey'
g.	padé	'work'	t.	w̃ĩnṍ	'wind'
h.	sɨgé	'to follow'	u.	tĩŋṍ	'Yapara rapids'
i.	siá	'to tie'	v.	sĩã́	'to kill'
j.	peé	'to bend'	w.	pẽẽ́	'to prepare soup'
k.	bipɨ́	'swollen'	x.	mĩpɨ̃́	'badger'
l.	ditɨ́	'to lose'	y.	nĩtɨ̃́	'coal'
m.	aká	'give food'	z.	ãkã́	'choke on a bone'

In attributing a special status to the first syllable, I follow Beckman (1995, 1997, 1998), who finds that the root-initial syllable often has a privileged status in triggering spreading and resisting change to its own featural specification. Beckman suggests that this is a consequence of faithfulness constraints that are position-sensitive, where the availability of such positions is defined by perceptual facilitation (drawing on observations of Steriade 1993c). Position-sensitive faithfulness will be discussed in more detail in chapter 3. Independent evidence for a special status of the first syllable in Tucanoan languages comes from nasalization in another Tucanoan language, Orejon (dialect described by Arnaiz 1988 and discussed in Pulleyblank 1989). In Orejon, nasality in vowels clearly originates in the first syllable and spreads to the right across a

2 The transcriptions in (6) follow Ternes, who asserts that voiced and voiceless fricatives are nasalized and fricated in nasal spreading. For more general discussion of nasalized fricatives see section 2.4.

3 Thanks to Geoff Pullum for first bringing the Tuyuca data to my attention.

4 Alternatively, Barnes suggests that the feature of nasality is affiliated underlyingly with the entire morpheme (1996: 31).

continuous sequence of voiced segments; voiceless segments block spreading. Importantly, nasalization is contrastive for vowels only in the initial syllable.

I assume that both voiced oral and nasal stops are 'phonemic' in Tuyuca, i.e. they may both occur underlyingly. This will be motivated as the analysis of Tuyuca develops: I posit underlying nasal stops since they are the best kind of segment with nasality and nasal vowels also occur in the language (cf. Ferguson 1963, who finds that the presence of nasal vowels almost always implies the occurrence of nasal stops in a language); also, evidence will be presented for the occurrence of underlying voiced obstruent stops. The surface complementary distribution of nasal and voiced stops is thus not a consequence of restrictions on underlying representations, but a consequence of nasal harmony. The nasalization of all voiced stops in nasal morphemes shows that obstruent stops are capable of actually undergoing nasal spreading. The existence of voiced stops with an obstruent status in Tuyuca is indicated both by the obstruent-realization of voiced stops in oral morphemes and by the patterning of voiced stops in nasal spreading across morphemes. In cross-morphemic spreading in Tuyuca, suffixes behave in one of two ways: they either take on the nasal quality of the stem to which they are affixed (8) or they are fixed in their nasality (9) (there are no prefixes in Tuyuca).

(8) Nasality alternations with /-ri/ 'imperative of warning'

a. Oral suffix alternant with oral stem
/tutí - ri/ → [tutíri] 'watch out or you will get scolded!'
scold - imp. of warning

b. Nasal suffix alternant with nasal stem
/h̃ɨ̃ɨ̃́ - ri/ → [h̃ɨ̃ɨ̃́r̃ĩ] 'watch out or you will get burned!'
burn - imp. of warning

(9) Suffixes with fixed nasality

a. Fixed oral suffix
/w̃ãkã́ - go/ → [w̃ãkãgó] 'she awakens'
wake up - evidential

b. Fixed nasal suffix
/koa - mã/ → [koamã́] 'allow me to dig'
dig - imp. of permission

A list of some Tuyuca suffixes by their nasalization categories is given in (10-11). Interestingly, suffixes that alternate exclude ones with initial stops or fricatives.[5] As Barnes (1996: 34) observes, this indicates that obstruents block nasal spread from stem to suffix, otherwise the gap of obstruent-initial suffixes in the alternating set would be purely accidental.

(10) Alternating suffixes:

a.	-a	animate plural
b.	-ha	contrast
c.	-ja	imperative
d.	-wɨ	evidential
e.	-wo	evidential
f.	-ri	imperative of warning
g.	-re	specifier
h.	-ro	adverbializer
i.	-ra	pl. nominative

(11)

Fixed oral suffixes:			Fixed nasal suffixes:		
a.	-a	recent past	o.	-h̃ã	emphatic
b.	-ja	evidential	p.	-j̃ã	try
c.	-wɨ	classifier	q.	-w̃ɨ̃	singularizer
d.	-wo	classifier	r.	-w̃õ	classifier
e.	-ri	inanimate sg. nominative	s.	-r̃ĩ	time(s)
f.	-re	inanimate pl. nominative			
g.	-sa	classifier	t.	-sã	continue action
h.	-ba	classifier	u.	-mã	classifier
i.	-da	classifier	v.	-nã	at that instant

5 Voiced velar stops behave somewhat differently from the others, because they can occur in alternating suffixes. Barnes gives the example, /-go/, a dependent verb suffix, which is realized as [go] after an oral morpheme and [ŋõ] after a nasal morpheme (1996: 35). Trigo (1988) offers a possible explanation. In her discussion of the related language, Tucano, which exhibits the same suffixal blocking effects, she argues that the velar nasal alternant is actually a placeless nasal segment, and thus belongs to a separate class from the stops. It has also been suggested that voiced velars tend to become nasalized in order to overcome the difficulty in maintaining voicing when there is a posterior oral closure. This has been hypothesized in regard to the [g] ~ [ŋ] allophony in Tokyo Japanese, where voiced velar stops occur as oral word-initially and nasal medially (McCarthy and Prince 1995; Itô and Mester 1997c).

j.	-ga	evidential	w.	-ŋã	diminutive
k.	-go	evidential			
l.	-pi	too much	x.	-pĩ	classifier
m.	-to	evidential	y.	-tõ	classifier
n.	-ka	large inanimate sg.	z.	-kã	also

The fact that voiced stops pattern with the obstruents in blocking nasal spread across morphemes is strong evidence that when oral they are obstruents themselves. This blocking effect would be wholly unexpected if oral voiced stops were posited as underlyingly oral sonorants rather than obstruents in Tuyuca, as Piggott (1992) and Rice (1993) have proposed for the related Tucanoan language, Southern Barasano. Sonorant stops, a set which includes nasals like [m] or [n] and possibly oral sonorant counterparts (as Piggott and Rice suggest), are highly compatible, indeed the best, with nasalization and would not be expected to block nasal spreading when less compatible segments such as glides and liquids undergo. On the other hand, obstruent stops are low on the scale of compatibility with nasalization, so they should only undergo nasalization when all segments that are more compatible do as well — this is the case within Tuyuca morphemes. Further, they are expected to be amongst the first classes of segments to block nasal spreading, consistent with their behavior in cross-morphemic harmony. The full system of Tuyuca nasal harmony forms a case study in chapter 3.

Nasal harmony within Tuyuca morphemes provides an example in which nasal spreading targets all classes of segments, including obstruents. This completes the exemplification of the hierarchical typology, summarized in (12).

(12) Hierarchical typology of nasal harmony

_①_Vowels___Glides____Liquids____Fricatives__ Obstruent stops___① *Spanish*
__Vowels_②_Glides____Liquids____Fricatives__ Obstruent stops___② *Sundanese*
__Vowels____Glides_③_Liquids____Fricatives__ Obstruent stops___③ *Malay (Johore)*
__Vowels____Glides____Liquids_④_Fricatives__ Obstruent stops___④ *Ijo (Kolokuma)*
__Vowels____Glides____Liquids____Fricatives_⑤_Obstruent stops__⑤ *Gaelic (A.cross)*
__Vowels____Glides____Liquids____Fricatives__ Obstruent stops_⑥_⑥ *Tuyuca*

← UNDERGOERS————————————BLOCKERS →

All of the variation in the set of non-undergoing (blocking segments) conforms to the one fixed hierarchy of segments and all variations given by the hierarchy are attested.

An analytical assumption I make for this typology is that all nasal harmony is strictly segmentally local, so the only possible outcome for a segment failing to participate in nasal harmony is for it to block spreading. Because of the strict locality, descriptively transparent segments will not be skipped but should be grouped with the segments that actually undergo harmony, so in Tuyuca, I claim that 'transparent' voiceless obstruents should be regarded as segments that participate in nasal harmony. This claim is key to achieving a complete typology with all hierarchical variants.

In order to verify the cross-linguistic application of this hierarchical typology, I compiled a database of nasal harmony patterns in over 75 languages, building on the background of surveys by Schourup (1972), Cohn (1993c), and Piggott (1992) (among other foundational work cited in 2.4). Patterns included in this database are those in which nasalization spreads across syllables or targets nonvocalic segments in the syllable. A condensed version of the database and discussion of its findings are given in an appendix to this chapter in section 2.4. I summarize here the key findings and relate them to the typology in (12).

The focal finding of the database is that variation in nasal harmony across languages bears out the implicational hierarchy outlined in (2). The study finds that if a segment blocks nasalization, all segments less compatible by the nasalization hierarchy will also block nasal spreading. Further, if a segment undergoes nasalization or behaves transparent, all segments more compatible with nasality will undergo nasal spreading. Importantly, transparency effects are limited to the class of obstruents, that is, only obstruents have ever been shown to surface as oral within a nasal harmony span; other segments become nasalized in this context. Obstruents are precisely the class for which there appears to be no example of nasalization of all segments, an unexpected gap under the assumption that all possible variants given by the implicational hierarchy actually occur. Filling this gap motivates the claim that transparent segments are 'undergoers' or targets of nasalization, so a language in which all segments are nasalized with the exception of some transparent obstruents corresponds to a language in which all segments undergo nasal harmony. We thereby derive a complete typology, in which all hierarchical variants are attested, and at the same time we explain the essentially complementary relationship between segments that become nasalized in nasal harmony and those that behave transparent. In addition, we derive the parallel implication in these two sets of segments, whereby if a segment becomes nasalized or behaves transparent, all more compatible segments also undergo nasalization.

The cross-linguistic generalizations thus support the hierarchical view of variation and the proposal that transparent segments should be understood as targets of nasal spreading. In chapter 3 I argue that transparency only occurs as the result of an opaque constraint interaction: one that arises to resolve a conflict between fully satisfying the nasal spreading constraint and avoiding violation of the constraint against nasalized obstruents. In the remainder of this chapter, I focus on the analysis of the undergoing and blocking behavior of segments

2.2 Analysis of the typology

The typology established by the database confirms that cross-linguistic variation in nasal harmony obeys the implicational hierarchy in (2). On the subject of transparent segments it shows that obstruents are the only segments to ever behave transparent to nasal harmony, and when they act transparent, all higher-ranked segments in the hierarchy undergo nasalization — they never block under these circumstances. This is explained by treating descriptively transparent segments as undergoers of nasal spreading. As undergoers, they are only expected to be targetted in nasal harmony when all higher-ranked segments are as well. This model of the typology yields one in which all variants given by the implicational hierarchy are attested. In this section, I develop an optimality-theoretic analysis of the hierarchical typology.

2.2.1 The constraints

To characterize the basic typology of nasal harmony, two kinds of constraints will be required: spreading constraints and nasal markedness constraints. I begin by examining the markedness constraints, arguing that they are arrayed in a hierarchy according to the compatibility of certain feature combinations with nasalization. I then go on to the formulation of the spreading constraint. Factorial ranking of the spreading constraint in relation to the nasal markedness hierarchy will derive the cross-linguistic variation. I defer discussion of faith constraints until section 2.3.

Drawing on a proposal initially made by Schourup (1972), I assume that all variation in the set of target segments in nasal harmony is based on the phonetically-grounded universal harmony scale of nasalized segments in (13), which corresponds to the implicational hierarchy in (2). (The notion of a ‘harmony scale’ is after Prince and Smolensky 1993. Hierarchical (in)compatibility is also discussed in Pulleyblank 1989; Piggott 1992; Cohn 1993a, c; Padgett 1995c; Walker 1995. See also Hume and Odden 1994 for a somewhat different yet related hierarchy based on impedence.)

(13) *Nasalized segment harmony scale*

a. nasal sonorant stop ≻ nasal vowel ≻ nasal glide ≻ nasal liquid ≻ nasal fricative ≻ nasal obstruent stop

b. A possible elaboration in featural terms:

nasal sonorant stop [+nas, +son, -cont] ≻ nasal vowel [+nas, +approx, -cons, +syll] ≻ nasal glide [+nas, +approx, -cons, -syll] ≻ nasal liquid [+nas, +approx, +cons] ≻ nasal fricative [+nas, +cont, -son] ≻ nasal obstruent stop [+nas, -cont, -son]

(13a) gives the harmony scale segregated by segmental class. In general nasal spreading appears to make class-based distinctions in the segments it targets. If it were necessary to make finer-grained distinctions by ranking nasalization of individual segments, this hierarchy could be made more detailed; however, this does not typically seem to be called for in nasal harmony. (13b) gives content to the segmental classes of (13a) in featural terms (the particular choice of features here is not crucial to what follows). It is important to note that in (13) [+nasal] is simply combined with the other feature specifications describing a given class of sounds, for example, a nasalized liquid will be [+approximant] in the output and a nasalized obstruent will be [-sonorant].

The nasalized segment hierarchy reflects the fact that a sonorant stop is most compatible with nasality and is most widely attested across inventories (Ferguson 1963, 1975; Maddieson 1984; Pulleyblank 1989; Cohn 1993a). In fact, it is not clear whether sonorant stops (e.g. [n]) ever occur without nasalization (but see Piggott 1992 and Rice 1993 for some suggested instances; as noted in the database, Ewe may also provide a case). Vowels are the next most widely attested nasal segment and are the most susceptible to acquiring nasalization in nasal spreading. The relative harmony of nasalized segments decreases gradiently through the hierarchy, ending with nasalized obstruent stops. Notice that although the ranking in (13) closely resembles the sonority hierarchy (see e.g., Sievers 1881; Jespersen 1904; Hooper 1972, 1976; Hankamer and Aissen 1974; Basbøll 1977; Steriade 1982; Selkirk 1984; Levin 1985; Zec 1988, Clements 1990), it crucially differs in the ranking of nasal sonorant stops, and thus the two cannot be fully equated. However, Cohn (1993a) notes that sonority plays a role in determining the compatibility of nasalization with continuants. Also, in the nasal harmony database it was discovered that there can be language-particular variability in the ranking of voiced stops and voiceless fricatives which seems to correspond to variability in the sonority hierarchy (this will be discussed in section 2.4). I suggest that this similarity stems from both the sonority hierarchy and the nasalization hierarchy having an overlapping basis in perceptibility. In the case of sonority, the basis of perceptibility is something like acoustic intensity. For the nasalization hierarchy the scale reflects nasal perceptibility (in addition to articulatory compatibility, as noted below). A nasal stop will be the best segment in conveying perceptible nasalization, since the acoustic properties of a nasal stop stem solely from nasal airflow. For continuant segments, nasal airflow is combined with oral airflow. Here it seems that perceptibility of nasality is enhanced by greater sonority, hence the overlap in the two hierarchies.

Overall, it is both articulatory/aerodynamic and acoustic/perceptual factors that contribute to the basis for the nasalization hierarchy, as noted by Cohn (1993a). For example, it is difficult to produce an audibly nasalized fricative because such a sound segment has articulatory/aerodynamic and acoustic/perceptual demands that are hard to satisfy at the same time. The nasal property requires that the segment be produced with a lowered velum, and nasal airflow undermines the needed build-up of pressure behind the oral constriction to produce frication (Ohala and Ohala 1993; Cohn 1993a; Ohala, Solé, and Ying 1998). As a consequence, perceptible achievement of either nasality or frication generally suffers in the production of nasalized fricatives. In a nasal airflow study of Coatzospan Mixtec, Gerfen (1996) finds that nasal airflow can be maintained during a voiceless coronal fricative with strongly audible frication, but the acoustic cues for nasalization are weak — the fricative is typically perceived as oral. On the other hand, nasalized voiced fricatives in Guaraní are produced with clearly perceptible nasalization but they lose audible frication: Gregores and Suárez describe /ṽ, ɣ̃, ɣ̃ʷ/ as ‘nasalized frictionless spirants’ (1967: 81-2).

With the harmony scale in (13), we can explain the variation in nasal harmony as variability in where languages make the cut between segments that are sufficiently compatible with [+nasal] to be undergoers and those that are not. Since Optimality Theory is based on the notion of ranked and violable constraints, it is well-suited to capturing this insight (Prince and Smolensky 1993, McCarthy and Prince 1993a). To implement this idea in Optimality Theory, we must recast the ranking of nasal (in)compatibility in terms of the nasalized segment constraint hierarchy in (14), where the less compatible a segment is with nasality, the higher ranked the constraint against it (following Walker 1995; see Prince and Smolensky 1993 for similar derivations of constraint hierarchies from harmony scales). The approach of using feature

cooccurrence constraints to achieve segmental blocking is one that builds on previous work by Kiparsky (1985), Pullyblank (1989), and Archangeli and Pulleyblank (1994).

(14) *Nasalized segment constraint hierarchy:*

a. *NASOBSSTOP » *NASFRICATIVE » *NASLIQUID » *NASGLIDE » *NASVOWEL » *NASSONSTOP

b. A possible elaboration in featural terms:

*NASOBSSTOP: * [+nas, -cont, -son] » *NASFRICATIVE:*[+nas, +cont, -son] » *NASLIQUID: *[+nas, +approx, +cons] » *NASGLIDE: *[+nas, +approx, -cons, -syll] » *NASVOWEL: *[+nas, +approx, -cons, +syll] » *NASSONSTOP: *[+nas, +son, -cont]

The feature cooccurrence constraints in this hierarchy may be stated in terms of features, as in (14b), but I will refer to the categories in (14a) for ease of exposition. Thus, *NASFRICATIVE, for example, refers to the constraint prohibiting the combination of features: [+nasal, +continuant, -sonorant]. Such constraints could be derived by conjunction of markedness constraints against individual features, i.e. *[+nas]&[+cont]&[-son] (conjunction after Smolensky 1995, 1997), although constraint conjunction need not be crucially assumed here. In section 2.4 it will be noted that there may need to be some limited variability in the ranking amongst constraints against nasalized obstruents.

The nasalized segment constraints will conflict with the constraint driving the spread of [+nasal]. In autosegmental representations it is generally assumed that spreading produces an outcome in which a feature is *multiply-linked* across a span of segments, as schematically illustrated in (15). Importantly, spreading does not produce *copying* of a feature specification onto neighboring segments, producing separate occurrences of the feature specification, as shown in (16). The output representation in (16) is also to be avoided on the basis of OCP violations.

(15) The multiply-linked outcome of feature spreading:

```
Input      S1 S2 S3
            |
          [+F]

Output     S1 S2 S3
            \  |  /
             [+F]
```

(16) Feature spreading is not satisfied by feature copying:

```
Input      S1 S2 S3
            |
          [+F]

* Output   S1   S2   S3      Spreading has failed for each feature occurrence
           |    |    |
         [+F] [+F] [+F]
```

To achieve the multiply-linked outcome of spreading, the spreading constraint needs to make reference not just to feature specifications but to individual *occurrences* of feature specifications. The output in (15) has one occurrence of the feature specification [+F], while the output in (16) has three occurrences of [+F]. The spreading constraint must demand that each feature occurrence be linked to every segment in some domain, such as the morpheme or Pwd (Padgett 1995b proposes a constraint modelled along these lines). This distinguishes the required outcome in (15) from the undesired one in (16). I propose to formulate the general spreading constraint as in (17).[6]

(17) SPREAD([F], D)
Let f be a variable ranging over occurrences of the feature specification F, and S be the ordered set of segments $s_1 ... s_k$ in a domain D. Let Assoc(f, s_i) mean that f is associated to s_i, where $s_i \in S$.

Then SPREAD([F], D) holds iff

i. $(\forall s_i \in S)\ [[\exists f\ (Assoc(f, s_i))] \rightarrow [(\forall s_j \in S)\ [Assoc(f, s_j)]]]$.

ii. For each feature occurrence f associated to some segment in D, a violation is incurred for every $s_j \in S$ for which (i) is false.

[6] I am grateful to Geoff Pullum for suggestions concerning the formal statement of this constraint.

The spreading constraint in (17) expresses the requirement that for any segment linked to an occurrence of a feature specification F in some domain D, it must be the case that all other segments in D are also linked to the same occurrence of F. This constraint is satisfied in the output of (15) but is violated in (16). The statement in part (ii) of the constraint defines how violations are to be tallied (following Zoll 1996). For every occurrence of F, a violation is reckoned for each segment to which that occurrence is not linked. In (16), a total of six violations are accrued with respect to spreading; each of the three feature occurrences in the output incurs two violations, one for each segment to which a given feature occurrence is not linked. It should be noted that some analysts have formulated feature spreading constraints in terms of generalized alignment constraints (proposed by Kirchner 1993 with applications by Pulleyblank 1993, 1996; Akinlabi 1996, to appear; Itô and Mester 1994; Cole and Kisseberth 1994, 1995; Walker 1995; Beckman 1998; cf. Ringen and Vago 1997). This is an alternative way of formulating feature spreading and for nasal harmony would not be crucially different from use of the spreading constraint expressed above and in what follows.

The specific kind of feature spreading we are concerned with is spreading of the feature specification, [+nasal]. An example of a nasal spreading constraint is given in (18). This constraint is formulated to spread nasal within the domain of the morpheme, a spreading constraint needed to obtain nasalization in morphemes in Tuyuca.

(18) SPREAD([+nasal], M)
Let n be a variable ranging over occurrences of the feature specification [+nasal], and S consist of the ordered set of segments $s_1 ... s_k$ in a morpheme M. Let Assoc(n, s_i) mean that n is associated to s_i, where $s_i \in S$.

Then SPREAD([+nasal], M) holds iff

i. $(\forall s_i \in S)\ [[\exists n\ (Assoc(n, s_i)] \rightarrow [(\forall s_j \in S)\ [Assoc(n, s_j)]]]$.

ii. For each feature occurrence n associated to some segment in M, a violation is incurred for every $s_j \in S$ for which (i) is false.

SPREAD([+nasal], M) requires that every occurrence of a [+nasal] feature on a segment in a morpheme be linked to all segments in that morpheme. It says nothing about feature occurrences on segments belonging to separate morphemes. Within a morpheme containing a nasal segment, violations with respect to spreading will be incurred for every oral segment in the output.

The formulation of the spreading constraint so far incorporates nothing explicit about the direction of spreading. For the bidirectional spreading of [+nasal] in Tuyuca morphemes, this is sufficient; the formulation of spreading in (18) correctly targets every segment in the morpheme. Further, as noted by Steriade (1995a), Padgett (1995b), and Beckman (1995, 1997, 1998), in many instances of spreading which appear to be unidirectional, the direction of spreading can be derived by calling on constraints encoding positional prominence. This is the case, for example, in most systems of vowel harmony, where a feature spreads from a peripheral syllable in the word. However, in some patterns of nasal spreading it is necessary to incorporate directionality into the spreading constraint, so it appears that positional prominence does not always play a role in determining the direction of spreading. Examples occur in the nasal harmony of Sundanese, Malay, and Ijo (exhibited in section 2.1), where nasality spreads in a specific direction from a nasal segment anywhere in the word. The need for making reference to the direction of spreading is particularly clear from comparison of the nasalization patterns in Malay and Capanahua (Panoan, Peru; Loos 1969), which target the same groups of segments but differ in directionality. In (4), we saw that nasalization in Malay spreads progressively from a nasal stop to vowels, glides, and glottals. Capanahua nasalization permeates the same set of segments, but the direction is regressive from a nasal stop, whether from a syllable onset or a syllable coda. Examples are given in (19).[7]

(19) Capanahua

a.	ʔ̃õnãmpãn	'I will learn'
b.	põj̃ãn	'arm'
c.	bãw̃ĩn	'catfish'
d.	warãn	'squash
e.	bĩmɯ	'fruit'
f.	t͡ʃipõŋki	'downriver'
g.	kajatãnaiʔ	'I went and jumped'
h.	kũ̃nt͡ʃap	'bowl'

7 Word-final nasals in Capanahua are deleted but still trigger nasal spreading, so I have shown them in the transcription here. It should be noted that Capanahua also deletes nasals in clusters containing a continuant consonant, in which case it triggers bidirectional spreading. For analysis of this interesting phenomenon, see Loos (1969) and Trigo (1988).

To obtain the different direction of spreading in languages like Malay and Capanahua, it must be possible to encode directionality in the spreading constraint. I propose to formulate directional spreading as in (20).

(20) SPREAD-L/R([F], D)

Let f be a variable ranging over occurrences of a feature specification F, and S be the ordered set of segments $s_1...s_k$ in a domain D. Let Assoc(f, s_i) mean that f is associated to s_i, where $s_i \in S$.

SPREAD-R([F], D) holds iff

i. $(\forall s_i \in S)\ [[\exists f\ (Assoc(f, s_i))] \rightarrow [(\forall s_j \in S)\ [j>i \rightarrow (Assoc(f, s_j))]]]$ where $1 \leq i, j, \leq k$.

ii. For each feature occurrence f associated to some segment in D, a violation is incurred for every $s_j \in S$ for which (i) is false.

SPREAD-L([F], D) holds iff

iii. $(\forall s_i \in S)\ [[\exists f\ (Assoc(f, s_i))] \rightarrow [(\forall s_j \in S)\ [j<i \rightarrow (Assoc(f, s_j))]]]$ where $1 \leq i, j, \leq k$.

iv. For each feature occurrence f associated to some segment in D, a violation is incurred for every $s_j \in S$ for which (iii) is false.

The formulation of spreading in (20) adds directionality by making reference to the place of a segment within the sequence of segments in the domain. For any occurrence of a feature specification f linked to a segment s_i, SPREAD-R requires that the feature specification occurrence be linked to any segment s_j which comes *after* s_i in the sequence of segments in the domain D. For s_j to succeed s_i in the sequence, j must be greater than i. SPREAD-L expresses a similar demand but requires that a feature occurrence on s_i be linked to any s_j coming *before* s_i in the sequence.

(21) gives the formulation of the rightward nasal spreading constraint that will be required for Malay.

(21) Spread-R([+nasal], Pwd)

Let n be a variable ranging over occurrences of the feature specification [+nasal], and S consist of the sequence of segments $s_1...s_k$ in the prosodic word P. Let Assoc(n, s_i) mean that n is associated to s_i, where $s_i \in S$.

Then SPREAD-R([+nasal], Pwd) holds iff

i. $(\forall s_i \in S)\ [[\exists n\ (Assoc(n, s_i))] \rightarrow [(\forall s_j \in S)\ [j>i \rightarrow (Assoc(n, s_j))]]]$ where $1 \leq i, j, \leq k$.

ii. For each feature occurrence n associated to some segment in P, a violation is incurred for every $s_j \in S$ for which (i) is false.

Let us consider the evaluation of the representations in (22) in relation to this constraint. The structures in (a) and (b) each perfectly satisfy SPREAD-R, because for any segment linked to [+nasal], all segments to the right of it are also linked to that same occurrence of the [+nasal] feature specification. On the other hand, (c) incurs one violation with respect to SPREAD-R, because one segment to the right of S_2 is not linked to [+nasal].

```
(22) a.  S1 S2 S3      b.  S1 S2 S3      c.  S1 S2 S3
          \  |  /              \  /              |
           [+N]                [+N]             [+N]
```

In cases of spreading where directionality need not be stated in the constraint, I will continue to use a simpler formulation like that in (17). Alternatively, this kind of spreading could be captured with two constraints, one spreading to the left and the other to the right.

Interaction of nasal spreading constraints and the nasalized segment constraint hierarchy will derive the hierarchical variation in the typology of nasal harmony. The spreading constraint and nasal markedness constraints conflict in the following way in a word with a nasal segment. Satisfying spreading requires selection of an output containing nasalized segments, violating the markedness constraint. On the other hand, optimizing with respect to markedness means avoiding forming nasalized segments, which forces violation of spreading. Before exhibiting these constraint interactions, however, it is necessary to address the issue of locality of feature spreading. Most phonological theories acknowledge that feature spreading is subject to some kind of locality condition. This is needed to rule out unattested long distance interactions, such as spreading of place features from one consonant to another across vowels. The view of locality that I adopt here is *strict segmental locality*, as termed by Ní Chiosáin and Padgett (1997). Strict segmental locality prevents multiple linking of a feature from skipping an intervening segment.

The motivation for a segmentally strict view of locality is reviewed and argued for in a paper by Ní Chiosain and Padgett (1997). Their work seeks to understand

asymmetries in long-distance feature spreading, namely that while features (or gestures) like vowel-place, [nasal], and [aspiration] spread long-distance (i.e. across at least CVC or VCV sequences), others such as [voice] and consonantal major place do not. Focusing primarily on the asymmetry in major place spreading, they find explanation in a view of major place features as inherently specified in oral stricture degree (Browman and Goldstein 1986, 1989; Padgett 1994, 1995c). They show that an important consequence of this assumption is that spreading of consonant major place through vowels will produce a 'bottle-neck' effect, that is, the consonantal stricture of the consonant will be imposed on the vowel, producing an ill-formed syllable nucleus. Combining this with a segmentally strict concept of spreading, they obtain the failure of major consonantal place to spread across vowels.[8] In contrast, the spreading of vowel major place features through consonants is possible, since superimposing a vocalic degree of stricture on a consonant will still yield a consonant, as the consonantal stricture will be maintained along with a secondary vocalic constriction. This is supported by coarticulation studies which find that vocalic gestures normally overlap consonants (e.g. Öhman 1966). Ní Chiosáin and Padgett present a detailed examination of Turkish vowel harmony, arguing that the vowel place spreading does not skip any segments and permeates consonants as well as vowels. They demonstrate that the apparent 'transparency' of consonants to the vowel harmony can be understood from the perspective of segment realization and contrast, which they work out in the framework of Dispersion Theory (Flemming 1995a). This independently-motivated realizational explanation contributes to theoretical parsimony by eliminating any need for a transparency-specific segment skipping device.

At this point we may note that the cross-linguistic typology of nasal harmony is highly suggestive of the segmentally strict view of locality. It has shown us that nasality spreads from segment to segment. Importantly, apparent skipping of segments in nasal spreading does not occur as an alternative to *blocking* for non-undergoers, rather systems with descriptively transparent segments fill the slot where we expect to find all segments *undergoing* nasalization. The set of segments that may become nasalized and those that behave transparent are essentially in complementary distribution. This is explained if transparency occurs as a realization of a segment near the extreme of incompatibility with nasalization when it undergoes nasal spreading. Positing 'transparent' segments as undergoers derives a typology in which all variants given by

8 Following Gafos (1996) and Flemming (1995b), Ní Chiosáin and Padgett point out that coronal consonant harmonies do not involve spreading of a major consonantal place, but rather features involving tongue shape or orientation (characterized by some analysts as [anterior] or [distributed]), which do not entail spreading of stricture as well.

the implicational nasalization hierarchy are attested. It also explains why voiced stops always undergo nasalization rather than block when voiceless stops behave transparent.

The requirement of segmentally strict locality follows more generally from the claim that a 'gapped configuration' like that in (23) is universally ill-formed.

(23) The gapped configuration: universally ill-formed

```
α  β  γ          where α, β, and γ are any segment
 \    /
  [F]
```

In prohibiting a configuration like that in (23), which violates segmental adjacency in feature linking, I follow Ní Chiosáin and Padgett (1993, 1997), Padgett (1995a), and Walker (1996) (McCarthy 1994; Flemming 1995b; and Walker and Pullum 1997 provide foundation; cf. also Allen 1951; Stampe 1979; Gafos 1996). More generally for a call on the ill-formedness of gapping across anchors to constrain locality, see Kiparsky (1981), Levergood (1984), Archangeli and Pulleyblank (1994), and Pulleyblank (1993, 1996), among others. It should be noted that some previous conceptions of locality permit α, β, and γ to be defined as projected targets, allowing skipping of non-target segments (see, for example, Archangeli and Pulleyblank on 'prosodic transparency' 1994: 358-9, also feature-geometric approaches make use of elaborated structure below the segment; Piggott 1992); however, under segmentally strict locality, α, β, and γ are interpreted as any segment, so spreading and linking must be between adjacent segments. Building on the insights of Articulatory Phonology (Browman and Goldstein 1986, 1989, 1990), segmental locality corresponds to understanding each instance of a feature specification as representing a continuous occurrence of some property or gesture. If a single instance of a feature specification is linked to separate segments, then the featural gesture must carry on uninterrupted between each of those segments to which it is linked.[9]

In describing the gapped configuration as universally ill-formed, I mean that it represents a structural configuration that may never be violated in the candidate set: it is not a structure that Gen is capable of producing (following Ní Chiosáin and Padgett 1997, see also Gafos 1996 for a similar result in the model of 'Articulatory Locality'). Ní Chiosáin and Padgett characterize the ill-formedness of gapping in terms of its failure to

9 An alternative approach adopting a violable notion of gapping is considered and rejected in chapter 5.

be *convex*. Their definition of a convex featural event is given in (24) (1997: 4; adapted from the definition of convex phonological event by Bird and Klein 1990).

(24) A featural event F is convex iff it satisfies the following condition:

For all segments, α, β, γ, if α precedes β, β precedes γ, α overlaps F and γ overlaps F, then β overlaps F.

As Ní Chiosáin and Padgett suggest, it is reasonable to assume that convexity holds of phonological representations without exception.[10] The ill-formedness of the gapped configuration in (23) may thus be understood in these terms: the gapped configuration is not a possible phonological representation because it is not a convex featural event.

The consequence of segmentally strict locality for the analysis of nasal harmony is this: spreading of [+nasal] may never skip a segment by linking across it. If nasalization of a particular segment is not possible because of nasalization markedness constraints outranking spreading, the only outcome that may occur is that the segment block spreading.

2.2.2 A factorial ranking typology

Prince and Smolensky (1993) hypothesize that typologies are derived by factorial constraint ranking, that is, the set of possible languages will be given by the grammars produced by all of the different possible constraint rankings. The previous section established two kinds of constraints: the spreading imperative and the nasalized segment constraints. Under the factorial ranking hypothesis then, a typology should be derived by all of the possible rankings of these constraints. It has been determined that the nasalized segment constraints are intrinsically-ranked with respect to each other. This leaves all of the different rankings of the spreading constraint in relation to the nasal markedness hierarchy.

The complete set of possible rankings are given in (25). These rankings match perfectly with the hierarchical variation observed in the sets of undergoing and blocking segments in nasal harmony (in (12)). Because of the locality condition, [+nasal] can never skip associating to a segment in the attempt to achieve nasal spreading. Since skipping segments is not an option in spreading, any nasalized segment constraints

10 Archangeli and Pulleyblank (1994: 38) also argue that the gapped configuration can be ruled out on a formal basis in terms of precedence; however, they relativize this to skipping of anchors. Thus if spreading were to target moras (as they suggest for vowel harmony), non-moraic segments may be skipped.

which dominate spreading will produce blocking effects, as it would be worse to form these nasalized segments than violate spreading. In contrast, nasalized segment constraints outranked by spreading will correspond to participating segments, as it is better to violate these constraints by forming the nasalized segments, than it is to violate spreading instead.

(25) Hierarchical variation through constraint ranking:

① *Spanish:*
*NASOBSSTOP » *NASFRIC » *NASLIQUID » *NASGLIDE » *NASVOWEL » **SPREAD[+nas]**
② *Sundanese:*
*NASOBSSTOP » *NASFRIC » *NASLIQUID » *NASGLIDE » **SPREAD[+nas]** » *NASVOWEL
③ *Malay (Johore):*
*NASOBSSTOP » *NASFRIC » *NASLIQUID » **SPREAD[+nas]** » *NASGLIDE » *NASVOWEL
④ *Ijo (Kolokuma):*
*NASOBSSTOP » *NASFRIC » **SPREAD[+nas]** » *NASLIQUID » *NASGLIDE » *NASVOWEL
⑤ *Scottish Gaelic (Applecross):*
*NASOBSSTOP » **SPREAD[+nas]** » *NASFRIC » *NASLIQUID » *NASGLIDE » *NASVOWEL
⑥ *Tuyuca:*
SPREAD[+nas] » *NASOBSSTOP » *NASFRIC » *NASLIQUID » *NASGLIDE » *NASVOWEL

For case ① (Spanish), which exhibits no nasal harmony, SPREAD[+nas] is ranked below all nasalization constraints, as it fails to force violations of any of these constraints. For ② (Sundanese), where only vowels undergo nasal harmony, SPREAD[+nas] dominates just the constraint against nasalized vowels; other nasalization constraints are ranked above SPREAD[+nas], since they remain unviolated. ③ (Malay) maintains the same ranking of the nasalization constraints with respect to each other but moves SPREAD[+nas] over the nasalized glide constraint as well. ④ (Ijo) moves SPREAD[+nas] up one more to dominate the constraint against nasalized liquids, and for ⑤ (Scottish Gaelic) SPREAD[+nas] moves one more again so that fricatives also undergo. Finally for ⑥ (Tuyuca), SPREAD[+nas] dominates all nasalization constraints, giving a pattern in which all segments undergo harmony. The *NASSONSTOP constraint is not shown here, because all of the underlying sonorant stops are already nasal, so this constraint will not conflict with satisfaction of SPREAD[+nas].

The overall ranking that has been established for the typology of nasal harmony is given in (26). A crucial feature of this pattern is that the ranking of nasalization

constraints with respect to each other remains constant according to the intrinsically-ranked hierarchy in (14).

(26) Summary of constraint ranking:

Nasalized segment constraints
|________________________|
(blocking segments)
↓
SPREAD[+nasal]
|______________|
(spreading imperative)
↓
Nasalized segment constraints
|________________________|
(target segments)

The ranking pattern is exemplified in (27-29). The tableau in (27) illustrates the pattern for Sundanese, with rightward spreading.[11] In this variation, only vowels undergo harmony, so the spreading constraint dominates the nasalized segment constraints only up to the constraint against nasalized vowels. The other nasalization constraints dominate spreading. Nasalization in candidates is marked with a tilde and brackets are used to delimit spans of an occurrence of a [+nasal] feature, i.e. [nã] implies that one nasal feature is linked to two segments and [n][ã] signifies that there is a separate nasal specification for each segment. In the optimal output, in (a), spreading extends only as far as the adjacent vowel, since extending any farther would violate a dominating nasalization constraint. In (b), [+nasal] links to every segment, satisfying spreading; however, this candidate loses, because it violates the higher-ranked constraints against nasalized glides and obstruents. Candidate (c) shows a similar problem in spreading up to the obstruent stop. Candidate (d) nasalizes every vowel in the word, but it fails on the basis of spreading because it does not derive nasalization of the second vowel by multiple-linking. In (e), no spreading takes place, and this too loses on an extra spreading violation.

[11] The following tableaux show the evaluation of candidates for a plausible input form. The input that corresponds to the actual underlying representation is determined by Lexicon Optimization discussed in section 1.3.3.

(27) Sundanese

	ŋajak	*NAS OBSSTOP	*NAS FRIC	*NAS LIQUID	*NAS GLIDE	SPREAD-R ([+nas], Pwd)	*NAS VOWEL	*NAS SONSTOP
☞	a. [ŋã]jak					***	*	*
	b. [ŋãj̃ãk̃]	*!			*		**	*
	c. [ŋãj̃ã]k				*!		**	*
	d. [ŋã]j[ã]k					****!	**	*
	e. [ŋ]ajak					****!		*

The variations in nasal harmony will differ from Sundanese only in the ranking of the spreading constraint. (28) illustrates the case of Ijo, where vowels, glides, and liquids undergo nasalization. For this pattern, a leftward spreading constraint is situated between the constraint against nasalized fricatives and the constraint against nasalized liquids.

(28) Ijo

	sɔɾɔ̃	*NAS OBSSTOP	*NAS FRIC	SPREAD-L ([+nas], Pwd)	*NAS LIQUID	*NAS GLIDE	*NAS VOWEL	*NAS SONSTOP
☞	a. s[ɔ̃ɾ̃ɔ̃]			*	*		**	
	b. [s̃ɔ̃ɾ̃ɔ̃]		*!		*		**	
	c. sɔɾ[ɔ̃]			**!*			*	

When the spreading constraint dominates all of the nasalized segment constraints, all segments will participate in nasal harmony. This is how I propose to treat Tuyuca:

(29) Tuyuca

	w̃ãti	SPREAD ([+nas], M)	*NAS OBSSTOP	*NAS FRIC	*NAS LIQUID	*NAS GLIDE	*NAS VOWEL	*NAS SONSTOP
☞	a. [w̃ãt̃ĩ]		*			*	**	
	b. [w̃ã]ti	*!*				*	*	
	c. w[ã]ti	*!**					*	
	d. [w̃ã]t[ĩ]	*!****				*	**	

The optimal output selected on the basis of this ranking is the one in (a), in which all segments are nasalized, including the voiceless obstruent stop. This segment is

described as oral, corresponding to a representation like that in (d), with a separate nasal feature on either side of the stop. However, since candidate (d) incurs a superset of the spreading and markedness constraint violations that (b) does, where the stop blocks spreading, (d) can never be optimal under any ranking of these constraints. A candidate like (a), with spreading to all segments, is the only one for which spreading can drive nasalization of the vowel following the stop. A grammar with this outcome is predicted by the factorial ranking hypothesis. Accordingly, I posit this as the basic analysis for languages with transparent segments in nasal harmony, and in chapter 3 I explore how the optimal candidate in (a) is mapped to the outcome in (d) in an opaque constraint interaction.

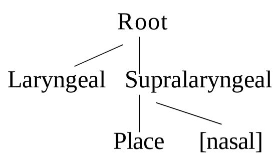
We have now seen that factorial constraint ranking of the spreading constraint in relation to the hierarchy of nasalized segment constraints derives precisely the hierarchical variation observed across languages. A claim underlying this typology is that descriptively transparent segments should be regarded as undergoing nasal spreading themselves, which has a more general grounding in the claim that spreading is segmentally strictly local. The analysis of 'transparent' segments as undergoers is supported by the observations of cross-linguistic variation on three fronts. First, the class of segments which may behave transparent are basically in complementary distribution with those that may become nasalized in nasal harmony. Second, a system in which all segments, including obstruents, undergo nasalization is predicted under the factorial ranking hypothesis: positing transparent segments as undergoers fills this slot given by the hierarchy. Third, this analysis explains the generalization that whenever a segment behaves transparent to nasal spreading, all segments more compatible with nasalization undergo spreading. As noted earlier, there is also external evidence for strict locality from the work of researchers on other spreading phenomena. Chapter 3 focuses on a means of deriving the surface orality of 'transparent' segments while maintaining the assumption of strict locality. There it is demonstrated that transparent segments can be captured under the 'sympathy' approach to opaque constraint interaction (McCarthy 1997, with developments by Itô and Mester 1997a, b), a mechanism with independent motivation in the theory.

2.2.3 The status of 'transparent' glottals

A brief word about the status of glottals (e.g. [h, ʔ]) in nasal harmony is required. In the transcription of these segments within nasal harmony spans, I have marked them as nasalized. Interpreting the articulatory correlate of [+nasal] as a lowered velum and not necessarily nasal airflow (Howard 1973; Cohn 1993a; Walker and Pullum 1997), the phonetic nasalization of glottal segments within nasal spans is uncontroversial (Howard 1973; Cohn 1990, 1993a; Ohala 1990; Durie 1985; Ladefoged and Maddieson 1996; Walker and Pullum 1997). Yet the phonological nasalization of these segments has been called into question by Cohn (1990, 1993a). Walker and Pullum (1997), on the other hand, argue that glottals can be nasalized in the phonology of a language.

Working in a feature-geometric framework, Cohn tentatively suggests that the feature [nasal] is not phonologically relevant for glottal segments. To implement this proposal, she proposes that [nasal] is a dependent of the supralaryngeal node in segment structure, a node that is absent in glottals and present in all supralaryngeal segments, as illustrated in (30) (from Cohn 1993a: 349).

(30)



With this model of segmental structure, spreading of [+nasal] will target only supralaryngeal segments (i.e. those with a supralaryngeal node), and glottal segments will be skipped. The locality assumed here, where adjacency is relativized to tiers, is standard for feature-geometric accounts. Under this view, gapping of [+nasal] feature linkage is allowed across a glottal segment provided the feature is associated to adjacent supralaryngeal nodes. Cohn's proposal achieves the outcome that glottals will not block nasal spreading, as is generally true of nasal harmony patterns (although a few languages with blocking by glottals are discussed in section 2.4). To produce the phonetic nasalization of glottal segments in nasal harmony spans, she draws on a separate level of phonetic implementation.

Walker and Pullum (1997) argue for a different view in which glottal segments can be nasalized in phonological representations. Walker and Pullum note that strong evidence for the possibility of phonologically nasalized glottals is provided by instances of languages with a phonemic nasal glottal continuant ([h̃] in Kwangali, Arabela).[12] Further support comes from the finding that nasal spreading is strictly local, as noted by Walker (1996) and argued for in this chapter. The skipping approach suggested by

12 On the possibility of a phonemic nasal glottal stop see Walker and Pullum (1997); Ní Chiosáin and Padgett (1997) also provide insightful discussion on this issue.

Cohn would seem to undermine this claim concerning locality; however, Walker and Pullum observe that there is no reason to posit glottals as skipped. The existence of phonemic nasal glottals shows that [nasal] must be allowed in the phonological representation of the class of glottal segments, and consequently, they neither can nor should be excluded from the set of possible targets of nasalization. The present account does not seek to achieve explanation through feature-geometric structures, the representational assumptions are rather that [nasal] may be linked to any segment; skipping is not an option, and if a segment fails to be permeated in nasal spreading, its only alternative is to block, as driven by feature cooccurrence constraints. We may thus conclude that glottal segments fully participate in nasal spreading in languages where they do not block. The cross-linguistic patterning of glottals in nasal harmony is discussed in the review of the database findings in section 2.4. There it is noted that glottal segments are typically grouped with the vocoids in terms of their compatibility with nasalization; however, their blocking behavior in a few languages suggests that in some cases they may be phonologically classified as obstruents. The role of perceptibility of nasalization in some instances of glottal blocking is also discussed.

Finally, it is worth pointing out that glottal stops in nasal harmony provide an interesting example where a segment undergoes nasal spreading even though there is no perceptual cue to the nasalization on the segment itself. In this case, the absence of perceptible nasalization does not mean that [+nasal] has failed to be realized during the segment; the property of having a lowered velum simply has no acoustic effect when there is a complete closure at the glottis. This kind of transparency is thus one where carrying a feature through a segment has no acoustic consequences, although the spreading feature is highly compatible from an articulatory perspective with the target segment. This kind of *false* transparency can be distinguished from cases of *true* transparency, where a segment that is highly incompatible with a spreading feature behaves transparent, i.e. the case of transparent obstruents in nasal harmony. These different kinds of transparency will be discussed further in chapter 3.

2.3 Interaction of the hierarchy with multiple constraints

In section 2.2.2, cross-linguistic evidence for the nasalization constraint hierarchy was presented. It was demonstrated that the nasal spreading constraint could occur ranked at different points in the hierarchy in different languages. The fixed ranking of the constraints in the nasalization hierarchy also makes the prediction that different constraints may be ranked at separate points in the hierarchy in the same language. I will now briefly examine two such cases.

The first example is found in Epena Pedee, a Choco language spoken in Colombia described by Harms (1985, 1994). Epena Pedee has two separate nasal harmony phenomena. It exhibits a rightward spreading triggered by a nasal vowel. This rightward spreading nasalizes vowels, glottals, glides, and liquids. It is blocked by voiced and voiceless stops, fricatives, and the trill. In addition to this rightward spreading, there is a regressive nasal spreading within the syllable that nasalizes the onset to a nasal vowel (all syllables in Epena Pedee are open). This produces nasalization of all segments except voiceless stops. Voiced stops in onsets nasalize to become fully nasal stops. Harms points out that Epena Pedee has three distinctive series of stops: voiced, voiceless unaspirated, and voiceless aspirated. Voiced oral and nasal stops both occur in the outputs of the languages but in a non-contrastive distribution: nasal stops occur only in the onset to a nasal vowel and voiced oral stops occur elsewhere. The nasal spreading is illustrated in (31). Note that obstruents at the edge of a nasal span are prenasalized. Underlying forms shown here follow Harms (1985).

(31) Epena Pedee

a.	/peɾõɾa/	[peɾ̃õɾ̃ã]	‘guagua (a groundhog-like animal)’
b.	/ũbɯsi/	[ʔũ^{m}bɯsi]	‘neck’
c.	/bẽdewe/	[mẽ^{n}dewe]	‘blind snake’
d.	/wãhida/	[w̃ãh̃ĩ^{n}da]	‘they went’ (go+past+plural)
e.	/k^{h}ĩsia/	[k^{h}ĩ^{n}siə]	‘think’
f.	/hõp^{h}e/	[h̃õ^{m}p^{h}e]	‘a species of fish’
g.	/wãit^{h}ee/	[w̃ãĩ^{n}t^{h}ee]	‘go’ (future)
h.	/dãwe/	[nãw̃ẽ]	‘mother’
i.	/bĩbĩajaa/	[mĩmĩə̃ɲãã]	‘work a lot’[13]
j.	/k^{h}ɯɾɯdã/	[k^{h}ɯɾɯnã]	‘eel’
k.	/hebẽdẽ/	[hemẽnẽ]	‘to play’
l.	/hẽsaã/	[h̃ẽs̃ãã]	‘stinging ant’

Interestingly, the two nasal harmony phenomena of Epena Pedee differ in their degree of strength. The rightward nasal spreading nasalizes sonorants but is blocked by

13 Harms gives the nasal in this word as [n], but his description of segmental alternations predicts that it should be the palatal nasal, as I have shown here.

obstruents, while the (leftward) nasalization within the syllable nasalizes sonorants and obstruents. This indicates that two nasal spreading constraints are active in Epena Pedee, one demanding nasalization within the domain of the syllable, and the other requiring rightward spreading in the word. To realize their different strengths, these constraints will be ranked at separate points in the nasalization hierarchy. The syllable spreading constraint must outrank all nasalization constraints, while the rightward nasal spreading constraint will be dominated by constraints against nasalized obstruents. The outcome is illustrated in (32-33).

(32) Blocking of right spreading by an obstruent

wãhida	SPREAD ([+n], σ)	*NAS OBSST	*NAS FRIC	SPREAD-R ([+n], Pwd)	*NAS LIQUID	*NAS GLIDE	*NAS VOWEL	*NAS SONST
☞ a. [w̃ãh̃ĩ]da				**		*	**	
b. [w̃ãh̃ĩd̃ã]		*!				*	***	
c. [w̃ã]hida				***!*		*	*	
d. w[ã]hida	*!			****			*	

(33) Nasalization of an obstruent in syllable-domain spreading

hẽsaã	SPREAD ([+n], σ)	*NAS OBSST	*NAS FRIC	SPREAD-R ([+n], Pwd)	*NAS LIQUID	*NAS GLIDE	*NAS VOWEL	*NAS SONST
☞ a. [h̃ẽs̃ãã]			*				***	
b. [h̃ẽ]s[ãã]	*!			***			***	
c. h[ẽ]s[ãã]	*!*			***			***	

The second example of constraints ranked at separate points in relation to the nasalization hierarchy comes from Ijo (Williamson 1965, 1969b, 1987). The nasal harmony pattern of Ijo was discussed in section 2.1: a nasal stop or nasal vowel triggers leftward spread through vowels, glides, and liquids; obstruents block nasal spreading. We have established that this spreading pattern comes about by ranking a leftward nasal spreading constraint between *NASFRICATIVE and *NASLIQUID in the nasalization hierarchy. Another break in the hierarchy is needed to obtain nasality as a phonemic property of nasal stops and vowels. This is achieved by ranking IDENT-IO[+nasal] over *NASVOWEL and *NASSONSTOP (see section 1.3.3 for background on this approach). This produces an outcome in which only vowels and nasal stops may trigger nasal spreading. An example of nasalization triggered by a nasal vowel is shown in (34).

After McCarthy and Prince (1995: 280), I use F'[nas] to indicate the class of constraints that dispose of other possible ways of satisfying nasal spreading, for example through deletion or denasalization of the nasal trigger segment.[14]

(34) Nasal vowel triggers in Ijo

	sɔɾɔ̃	*NAS OBSST	*NAS FRIC	F' [nas]	SPREAD-L ([+n], Pwd)	*NAS LIQUID	*NAS GLIDE	ID-IO [+nas]	*NAS VOWEL	*NAS SONST
☞	a. s[ɔ̃ɾ̃ɔ̃]				*	*			**	
	b. [s̃ɔ̃ɾ̃ɔ̃]		*!			*			**	
	c. sɔɾ[ɔ̃]				**!*				*	
	d. sɔɾɔ			*!				*		

The tableau in (35) shows the operation of the constraint hierarchy on an input with a nasalized liquid. Here, the ranking of IDENT-IO[+nasal] below *NASLIQUID will cause the liquid to surface as oral.

(35) No 'phonemic' nasal liquids in Ijo

	ɾ̃a	*NAS OBSST	*NAS FRIC	F' [nas]	SPREAD-L ([+n], Pwd)	*NAS LIQUID	*NAS GLIDE	IDENT-IO[+nas]	*NAS VOWEL	*NAS SONST
	a. ɾ̃a					*!				
☞	b. ɾa							*		

More generally on the subject of inventories, the nasalization hierarchy predicts that inventories will exhibit the same kinds of implications as spreading, that is, if a nasalized segment occurs in the inventory of a language, all more compatible segments will also have nasal counterparts in the inventory and if a segment has no nasal counterpart in an inventory, all less compatible segments will also occur only oral in the inventory. This may be modulated, however, by the demands of contrast (as will be discussed in 2.4). For the most part, inventories of the languages of the world bear out this prediction (see discussion in Pulleyblank 1989; Cohn 1993a; Ferguson 1963, 1975 provides foundation). Almost every language of the world has nasal stops as part of its

14 Given that spreading outranks IDENT-IO[+nasal], I assume here that denasalization of the nasal trigger must always violate something other than just IDENT-IO[+nasal]. This is part of a general question of why spreading can never be satisfied by simply deleting the feature to be spread. The matter is one that I will leave for further research.

inventory (97%; UPSID; Maddieson 1984).[15] Distinctively nasal vowels occur considerably less frequently (in less than 25% of the languages in UPSID). Nasalized continuant consonants are contrastive in the inventories of languages only rarely. In those inventories with nasalized continuants, it is generally the case that the implications given by the nasalization hierarchy holds. The implication that the presence of nasal vowels will imply nasal stops was first noted by Ferguson (1963). Ijo provides an example of a language which has distinctively nasalized vowels in its inventory as well as nasal stops.[16] UMbundu, a Benue-Congo language of Angola, is a more extreme case. UMbundu is noted by Schadeberg (1982) to have a contrastively nasalized voiced fricative /ṽ/. In addition to this, the inventory of this language has nasal stops, nasal vowels, a nasal glottal, nasal glide, and nasal liquid.[17] In a survey of the status of nasalized continuants, Cohn (1993a) notes that the languages with nasalized continuant consonants (including nasalized glides) do not always have nasal vowels. Cohn points out that some of these nasalized segments emerge through historical or synchronic weakening of other nasalized segments, such as palatal or velar nasals, recalling patterns discussed by Trigo (1988). This is a promising direction for pursuing an understanding of inventory asymmetries in the case of nasalized continuant consonants.

2.4 Appendix: The nasal harmony database

2.4.1 Summary and discussion

In this section I present a condensed version of the database of nasal harmony patterns. This database contains entries for over 75 languages. An important result of this comprehensive survey is that it shows that cross-linguistic variation obeys the hierarchical typology of nasal harmony in (12). There also proves to be some interesting variability in the ranking of glottals and voiced stops versus voiceless fricatives, which is discussed below.

15 Thompson and Thompson 1972 cite three language families of the Pacific Northwest region some members of which have no nasal in their inventory: Chemakuan, Wakashan, and Salishan.

16 For several Amazonian languages, it has been observed by various researchers that a phonemic analysis of the language need only posit nasality as 'underlying' on vowels. However, all of these languages still admit nasal stops in the output inventory, and it appears that only economy of phonemes excludes nasal stops from the 'underlying' inventory (as argued for Tuyuca, voiced obstruent stops must be included in the inventory). This issue becomes less important in the view of inventories under OT, as will be seen in chapter 3.

17 This concept of the UMbundu inventory is that proposed by Schadeberg (1982). Cohn (1993a: 332) suggests an alternative interpretation in which nasality is a lexical property of the last syllable of the stem and nasalized continuants are derived.

The database assembles substantial information about each language, including the language name, family, and location, the inventory of segments, the segments triggering nasal spread, blocking segments, descriptively transparent segments, nasalizable segments, prosodic conditions on blocking or triggering segments, direction of spreading, domain of spreading, occurrence of prenasalization, whether nasalization functions as a morpheme, references, and any further related facts. A condensed version of the database is appended at the end of this section. Information included in these entries is as follows (organized by columns in data presentation):

1. Language: Language name, dialect, language family, and where spoken.
2. Triggers: Segments initiating nasal spreading.
3. Through: Segments propagating nasalization, i.e. those that are nasalized or descriptively transparent.
4. Direction: Direction of nasal spreading.
5. Comments: Details related to nasal harmony in the language.
6. Selected references.

Nasal spreading patterns included here are those in which nasality spreads across syllables or nasalization targets nonvocalic segments in the syllable.[18] The information is based on my own examination of primary source descriptions (wherever possible). In addition, three secondary sources provided significant foundational background to this research. These are Cohn's (1993c) survey of the status of the feature [+nasal] across a wide range of languages and the surveys of nasal spreading reported in Schourup (1972, 1973) and Piggott (1992). Other important secondary sources include Court (1970), papers in Ferguson, Hyman, and Ohala, eds., (1975), Anderson (1976), Hart (1981), van der Hulst and Smith (1982), Beddor (1983), Bivin (1986), Kawasaki (1986), Pulleyblank (1989), and papers in Huffman and Krakow, eds., (1993).

The central finding of the survey is that variation in nasal harmony across languages verifies the implicational hierarchy outlined in section 2.1. The study finds that if a segment blocks nasalization, all segments less compatible by the nasalization hierarchy will also block nasal spreading, and if a segment undergoes nasalization or behaves transparent, all segments more compatible with nasality will undergo nasal spreading. Transparency effects are limited to the class of obstruents, that is, only

18 A long-distance nasalization pattern occurring in certain Bantu languages (Ao 1991, Odden 1994, Hyman 1995, Piggott 1996) is discussed in chapter 6. I argue that these alternations are examples of cooccurrence effects, not nasal spreading.

obstruents have ever been shown to surface as oral within a nasal harmony span; other segments become nasalized in this context. Obstruents are also the class for which there is no example of nasalization of all segments. Filling this gap motivates the claim that transparent segments should be understood as targets of nasal spreading, so that a language with nasalization of all segments except some transparent obstruents actually corresponds to a language in which all segments undergo nasal harmony. We thereby derive a complete typology in which all variants are attested.

The implicational hierarchy defined five basic patterns of nasalization, corresponding to each step in the hierarchy of segmental classes (excluding patterns in which no segments undergo nasal spreading). A summary of the languages in the database corresponding to each of these variants is given in (36) below with shaded portions of the hierarchy identifying classes of segments which block nasal spread. Portions of the hierarchy which are not shaded identify classes of segments which nasalization spreads through. These segments either become nasalized or behave transparent. In a few cases. only a portion of a class of segments are permeated by nasalization, in which case the class is not shaded. These finer-grained instances are discussed below and are detailed in the database in 2.4.2. Note that the glottals category has been added here between the classes of vowels and glides. In the majority of languages in which vocoids undergo nasalization, glottals do not inhibit nasal spreading. However, the glottals category is enclosed in parentheses because some descriptions are not explicit on the behavior of glottals in nasal harmony, and there is at least one instance in which glottals block when glides undergo. This signals some variability in the cross-linguistic compatibility of glottals with nasalization.

(36) Summary of languages in the five main patterns of nasal harmony

i. Vowels	(Glottals)	Glides	Liquids	Fricatives	Obstruent stops

9 examples in database:

Language	Dialect	Family	Location
Barasano	Northern	Tucanoan	Colombia
Guahibo		Guahibo-Pamaguan	Colombia, Brazil
Mixtec	Ayutla	Mixtecan	Mexico
Mixtec	Mixtepec	Mixtecan	Mexico
Mixtec	Molinos	Mixtecan	Mexico

Mixtec	Silacayoapan	Mixtecan	Mexico
Otomi	Pame	Otopamean	Mexico
Sundanese		Hesperonesian	Indonesia
Tinrin		Melanesian	

ii. Vowels (Glottals) Glides Liquids Fricatives Obstruent stops

28 examples in database:

Language	Dialect	Family	Location
Acehnese		Hesperonesian	Indonesia
Aguaruna		Jivaroan	Peru
Arabela		Zaparoan	Peru
Bariba		Voltaic	Nigeria
Breton		Celtic	France
Capanahua		Panoan	Peru
Chinantec	Tepetotutla	Chinantecan	Mexico
Dayak	Kendayan	Indonesian	Borneo
Dayak	Land, Bukar Sadong	Hesperonesian	Indonesia
Dayak	Land, Mĕntu	Indonesian	Sarawak
Dayak	Sea	Indonesian	Sarawak
Konkani		Indo-Iranian	India
Lamani		Indo-Aryan	India
Madurese		Malayo-Polynesian	Indonesia
Malay	Johore	Indonesian	Malaysia
Malay	Ulu Muar	Indonesian	Malaysia
Marathi		Indo-Aryan	India
Maxakali		(isolate)	Brazil
Melanau	Mukah	Austronesian	Sarawak
Orejon	(after Velie & Velie)	Tucanoan	Peru
Oriya	Colloquial variety	Indo-Aryan	India
Rejang		Austronesian	South Sumatra
Saramaccan		(creole)	Surinam
Seneca		Iroquoian	Canada, USA
Terena/o		Arawakan	Brazil
Warao		(isolate)	Venezuela, Guyana

Urak Lawoi’		Hesperonesian	Thailand, Malaysia
Urdu		Indo-Iranian	Pakistan, India

iii. Vowels (Glottals) Glides Liquids Fricatives Obstruent stops

15 examples in database:

Language	Dialect	Family	Location
Edo		Kwa	Nigeria
English	Midwestern	Germanic	USA
Epena Pedee		Choco	Colombia (R spreading)
Epera		Choco	Panama (cross-morph.)
Ewe/Gbe		Kwa	Ghana, Togo, Bénin, Nigeria
Hindi		Indo-Iranian	India, Pakistan
Ijo	Kolokuma	Kwa	Nigeria
Isoko	Ozoro	Kwa	Nigeria
Kayan	Uma Juman	Austronesian	Sarawak
Kpelle		Mande	Liberia, Guinea
Mandan		Siouan	USA
Spanish	South Castilian	Romance	
Tucano		Tucanoan	Colombia (cross-morph.)
Tuyuca		Tucanoan	Colombia, Brazil (cross-mor.)
Urhobo		Kwa	Nigeria
Yoruba		Kwa	Nigeria

iv. Vowels (Glottals) Glides Liquids Fricatives Obstruent stops

4 examples in database:

Language	Dialect	Family	Location
Ennemor		Semitic	Ethiopia
Itsekeri		Kwa	Nigeria
Scottish Gaelic	Applecross	Celtic	Scotland
UMbundu		Benue-Congo	Angola

v. Vowels (Glottals) Glides Liquids Fricatives Obstruent stops

29 examples in database:

Language	**Dialect**	**Family**	**Location**
Apinayé		Ge	Brazil
Barasano	Northern	Tucanoan	Colombia (L spreading)
Barasano	Southern	Tucanoan	Colombia
Bribri		Chibchan	Costa Rica
Cabécar	Southern	Chibchan	
Cabécar	Northern	Chibchan	
Cayuvava			Bolivia
Cubeo		Tucanoan	Colombia
Desano		Tucanoan	Colombia, Brazil
Epena Pedee		Choco	Colombia (L spreading)
Epera		Choco	Panama (domain: morph.)
Gbeya		Adamawa-Eastern	Central African Republic
Gokana		Benue-Congo	Nigeria
Guanano		Tucanoan	Colombia
Guaraní		Tupí	Paraguay, Brazil, Colombia
Guaymi			Panama
Igbo	Ohuhu	Igbo	Nigeria
Icua Tupí		Tupí-Guaraní	Brazil
Kaiwá		Tupí-Guaraní	Brazil
Mixtec	Atatlahuca	Mixtecan	Mexico
Mixtec	Coatzospan	Mixtecan	Mexico
Mixtec	Ocotepec	Mixtecan	Mexico
Orejon	(after Arnaiz)	Tucanoan	Peru
Parintintin		Tupí-Guaraní	Brazil
Shiriana		Shirianian	Venezuela, Brazil
Siriano		Tucanoan	Colombia, Brazil
Tatuyo		Tucanoan	Colombia
Tucano		Tucanoan	Colombia (domain: morph.)
Tuyuca		Tucanoan	Colombia, Brazil (dom: mor.)

The above summary shows that all of the cases of nasal harmony examined can be classified according to the hierarchical typology. It also indicates that some patterns are more widespread than others. Nasalization of vocoids (and glottals) is one of the most common patterns, with concentrations of languages in the Pacific (Austronesian family), India (Indo-Iranian family), and Central and South America. A second common pattern spreads nasalization through all classes of segments. This pattern is frequent in the indigenous languages of South and Central America, especially in the Tucanoan and Tupí-Guaraní branches of the Amazonian language family. Nasalization of just the class of sonorants is somewhat less common but is nevertheless well-attested in the Kwa languages of Nigeria and in the cross-morpheme spreading pattern of some South/Central American languages, as well as in a scattering of other languages. The category with the least members is the one in which nasalization spreads through sonorants and fricatives but is blocked by obstruent stops. This suggests that if the demand of nasal harmony is strong enough to spread through fricatives, it generally is strong enough to target stops as well.

The reports of nasalized fricatives deserve some comment. The data in (6) showed nasalization of voiced and voiceless fricatives in the Applecross dialect of Scottish Gaelic, following Ternes's own reports on the basis of contact with Gaelic speakers. In a survey of occurrences of nasalized continuants, Cohn (1993a) cites three other languages reported to have nasalized fricatives: Waffa (Papuan, Papua New Guinea; Stringer and Hotz 1973), UMbundu (Niger-Kordofanian, Angola; Schadeberg 1982) and Igbo (Niger-Kordofanian, Nigeria; Green and Igwe 1963). Some other examples we may add include Epena Pedee (Harms 1985), Ennemor (Hetzron and Marcos 1966), and Icelandic (Pétursson 1973 and Einarsson 1940 cited by Padgett 1995c: 51 n. 32). Yet Ohala and Ohala (1993) have questioned the possibility of nasalizing fricatives articulated forward of the velum. They suggest that it is impossible for such sounds to be produced with a lowered velum, because the open nasal airway will prevent the build-up of air pressure in the oral cavity needed to produce the characteristic fricative turbulence (1993: 227-8; see also J. Ohala 1975 for this claim concerning voiced fricatives). Certainly, there is a tendency for so-called 'voiced fricatives' to be produced as frictionless continuants under nasalization (Ohala 1983; Pickett 1980). However, there is good support for the occurrence of nasalized fricatives in some languages. Descriptions of Epena Pedee and Icelandic are explicit in claiming that nasal airflow is maintained during the fricative. Ladefoged and Maddieson's review of the topic finds that 'there is good evidence that a nasalized fricative occurs in UMbundu' (1996: 134). This segment is described by Schadeberg as a 'voiced nasalized labial continuant,' transcribed as [ṽ], and after explicitly remarking on Ohala's claim that such segments are impossible, Schadeberg notes that this segment contrasts with a nasalized labial approximant [w̃] (1982: 127). Evidence for a voiceless nasalized fricative comes from Gerfen's (1996) instrumental investigation of Coatzospan Mixtec (Mixtecan, Mexico), where he finds that nasal airflow persists through a so-called 'transparent' voiceless coronal fricative [ʃ]. It should be noted that while Gerfen's results are strongly suggestive that it is possible to produce a voiceless fricative with a lowered velum, his technique gauged velum position indirectly through airflow measurements. For absolute certainty on this issue, a direct measurement of velum position is needed.

Recent work by Ohala, Solé, and Ying (1998) investigated the matter of nasalized fricatives by creating a pseudo-velopharyngeal valve. They created the valve by inserting catheters of various sizes into the oral cavity (via the buccal sulcus and the gap behind the upper molars) and intermittently opening and closing the outer openings. Catheters of different sizes simulated differences in velo-pharyngeal opening; although as Ohala, Solé, and Ying note, the size of catheter aperture may not correspond precisely to the impedance produced by the same velo-pharyngeal opening, because the length of the catheters was greater than the length of the nasal passage. They discovered that for the smallest catheter, 7.9 mm^2, there was no significant effect on the level of pharyngeal pressure (i.e. pressure behind the constriction for the buccal fricative) and no detectable effect on the quality of the fricative. For catheters with areas of 17.9 mm^2 and above they found that pharyngeal pressure dropped considerably, especially for voiced fricatives. The pressure drop was weaker in voiceless fricatives because the open glottis in these segments allowed greater airflow up from the lungs to combat a drop in pressure. Because of the pressure drop from the catheter, voiced fricatives became frictionless continuants and aperiodic acoustic energy was reduced in voiceless fricatives in the higher frequencies. The findings of this study clearly support the claim that nasalization is antagonistic to fricative sounds; however, this antagonism appears gradient such that the greater the velo-pharyngeal aperture, the greater the reduction in frication, and conversely, the smaller the velo-pharyngeal aperture, the less perceptible the nasalization. Balancing this gradience with the findings of various researchers supporting the existence of nasalized fricatives, I assume that they do occur in some languages, although typically either degree of frication or perceptibility of nasalization will suffer in the production of these segments.

Examination of the languages in which nasalization spreads through some obstruents suggests that there is cross-linguistic variability in the ranking of voiceless

fricatives and voiced stops in the nasalization hierarchy. In the class of obstruents it is always the case that voiced fricatives are the most compatible with nasalization and voiceless stops are the least compatible. Continuancy and voicing thus are qualities favoring nasalization of obstruents. For segments with just one of these qualities, languages appear to vary in whether continuancy or voicing is more compatible with nasalization. This is illustrated by comparison of the patterns in (37).

(37) Cross-linguistic variation in nasalization of obstruents

Through		Blocking		
Vcd. fricatives	Vcls. fricatives	Vcd. stops	Vcls. stops	*e.g. Itsekeri, Ennemor*
Vcd. fricatives	**Vcls. fricatives**	Vcd. stops	Vcls. stops	*e.g. Scottish Gaelic (Applecross)*
Vcd. fricatives	**Vcd. stops**	Vcls. fricatives	Vcls. stops	*e.g. Epera, Orejon, Parintintin*
Vcd. fricatives	Vcls. fricatives	Vcd. stops	Vcls. stops	*e.g. Tuyuca, Tucano, Barasano.*

So far the hierarchy has segregated obstruents according to their continuancy, but the nasalization pattern in languages such as Epera, Orejon (dialect described by Arnaiz), and Parintintin indicates that separation by voicing is also a useful segregation. For languages such as these, the lower end of the compatibility hierarchy can be modified to rank voiced obstruents over voiceless ones. This mirrors variability across languages in the ranking of these classes of segments in the sonority hierarchy (cf. Hooper 1972, 1976 versus Steriade 1982). The source for parallels between the nasalization hierarchy and the sonority hierarchy was discussed in 2.2.1. Note that the occurrence of a pattern targetting just voiced fricatives (in Itsekeri and Ennemor) shows that languages may make finer-grained distinctions than those precisely matching the five major classes of segments. The five-way classification is thus useful for a general typology, but we might recognize that within these classes themselves, subclasses or even individual segments may be scaled according to their compatibility with nasalization.

Another cross-linguistic variability concerns the ranking of glottals in the implicational hierarchy. In the database we find that in the majority of nasal harmony patterns, nasalization spreads through any glottal segments in the language, i.e. the segments [h, ʔ] (although sometimes the behavior of glottals in nasalization is not discussed in the source). This tendency for glottals to undergo nasal spreading can be explained in terms of the articulatory compatibility of these segments with nasalization, since producing these segments with a lowered velum does not in any way interfere with the glottal articulation (see Walker and Pullum 1997 and references therein; also discussion in 2.2.3; cf. Cohn 1993a). Further, as noted in discussion of the 'rhinoglottophilia' phenomenon (Matisoff 1975; J. Ohala 1975), the acoustic effect of a glottal continuant on a neighboring vowel can resemble that of a lowered velum, actually favoring the interpretation of vowels as nasal when adjacent to [h]. On the other hand, the patterning of glottal segments in some languages suggests that they can sometimes be phonologically classified as obstruents, i.e. as [-sonorant] segments that are incompatible with nasalization. A possible case of blocking by glottal fricatives occurs in Terena, an Arawakan language of Brazil. Terena marks first person forms with nasalization of a morpheme from left to right, and [h] and [hʲ] pattern with the obstruents in blocking nasal spread. Bendor-Samuel (1960: 349) analyzes these segments as true fricatives (rather than glides, for example), noting that [hʲ] is actually produced with an alveolar constriction and that both [h] and [hʲ] function phonologically in the same way as [s] and [ʃ]. For glottal stop, blocking occurs in the Austronesian language, Rejang, spoken in South Sumatra. McGinn (1979: 187) observes that glottal stop patterns with the obstruents in blocking the rightward spread of nasality from a nasal stop, e.g. [mãʔaʔ] 'approach'; cf. [nĩj̃õw̃ã] 'coconut'. Harrison and Taylor (1971: 17) note that in Kaiwá, a Tupí-Guaraní language of Brazil, nasalization spreads through glottal stop in normal speech, but in slow speech [ʔ] blocks nasal spreading. It is also conceivable that the dispreference in some languages for a nasalized glottal stop has an acoustic/perceptual basis. Ní Chiosáin and Padgett (1997) have pointed out that nasalization of glottal stop is poor in achieving perceptible nasalization on the individual segment (see also discussion in Walker and Pullum 1997). The perceptibility problem is quite clear: because there is full stoppage of air behind the velum at the glottis, there can be no nasal airflow during a glottal stop. Thus, even though glottal stop can be 'nasalized' by being produced with a lowered velum, there will be no acoustic cue during the stop itself to signal the nasalization. The above cases suggest that while glottals most commonly pattern with the vocoidal segments in terms of their tendency to undergo nasalization, other factors can come into play, such as the phonological classification of these segments with obstruents rather than glides or perhaps the perceptibility of nasalization.

The implicational hierarchy is a good predictor of the likelihood of segments to undergo nasalization, but the nasal harmony database finds that other factors can also contribute to patterns of nasalization. One such factor is the demand of maintaining perceptible contrasts. It is well-known that nasalization tends to obscure the perceptibility of vowel height contrasts, evidenced, for example, by the universal

generalization that the number of nasal vowels in a language never exceeds the number of oral vowels (Ruhlen 1975, 1978; Bhat 1975; Crothers 1978; Beddor 1983; Wright 1986; Padgett 1997, among others). The demand to preserve vowel height contrasts can contribute to blocking effects in nasal spreading. An example of this occurs in the Applecross dialect of Scottish Gaelic. Scottish Gaelic has four vowel heights in its oral vowels (high, mid-high, mid-low, low) and three vowel heights in its nasal vowels (high, mid-low, low); thus, the oral mid-high vowels [e, ə, o] are missing phonemic nasal counterparts. This contrast-driven gap in the nasal vowel inventory is also apparent in nasal spreading: the oral mid-high vowels always block nasalization from an adjacent syllable, but vowels of other heights become nasalized. Here the demand to maintain perceptible vowel height contrasts outranks the demand of nasal spreading, producing blocking by a specific vowel height. More generally, in the very common phenomenon of nasalization of vowels by tautosyllabic nasal consonants, it is often the case that nasalization is restricted to certain vowel heights (see surveys in Schourup 1972, 1973; Beddor 1983). Further, degree of nasalization may sometimes vary with vowel height. In Yoruba, for example, progressive nasalization of vowels after a tautosyllabic nasal consonant is reported to produce heavy nasalization of high and low vowels, but light nasalization in the mid vowels [e, ɛ, o, ɔ] (Ward 1952: 13).[19]

Vowel backness also appears to interact with blocking in some cases. In Guaymi, spoken in Panama, the left-to-right nasalization which marks a near past completed action in class II verbs is blocked by back vowels but targets front vowels and voiced consonants (Bivin 1986 citing Kopesec and Kopesec 1975). In addition, Schourup (1973; 192) notes that vowel nasalization affects only front vowels in Sora (Munda; India; Schourup 1973 citing personal communication with Stampe) and Island Carib (Arawakan; Dominica; Taylor 1951). As a factor in perceptible degree of nasalization, Williamson (1965: 17) reports that in Ijo, back vowels are perceived as more nasalized than front ones (although kymograph records do not show a significant difference in the actual degree of nasalization in this environment). Yet Beddor (1993) notes that the acoustic consequences of nasalization for the perception of vowel backness is not entirely clear. Perhaps the strongest evidence for an interaction comes from Wright (1986), who found that nasalization caused front vowels to be perceived as more back than their oral counterparts. However, findings for the back vowels were less uniform with [õ] perceived as more front than [o] and high back nasal vowels perceived as slightly farther back than their oral versions. Wright's study suggests that nasalization

19 [ɔ] is sometimes an exception to this generalization. Ward reports two words, [ɔmɔ̃] 'child' and [mɔ̃] in which [ɔ] has strong nasalization.

may have some neutralizing effect on the perception of vowel backness. However, it is conceivable that the blocking behavior of back vowels could be another instance of the vowel height effect. Drawing on the findings of Hardcastle (1970) and K. Stevens (1968), Lindblom (1986) notes three sets of facts concerning a front/back asymmetry in the vocal tract: (i) articulators have increased mobility at anterior locations (ii) there is a greater supply of structures for sensory control towards the front of the mouth, and (iii) acoustic-perceptual effects appear to be stronger at the front than at the back. Combining these observations, Lindblom speculates that the front/back asymmetry may produce a richer range for contrast in vowels produced in the front versus the back of the mouth. If this is so, then we may expect vowels in the back region to be more resistant to nasalization, because of the blurring effect of nasalization on height contrasts. For a firmer grasp of the factors involved in this phenomenon, more investigation is needed.

Rate of speech and stress may effect patterns of nasalization. Two languages in the study report that nasalization spreads through more segments in faster speech. In Kaiwá, glottal stop blocks nasal spreading only in slow speech. In Epera, a Choco language of Panama, voiceless stops normally block the spreading of nasalization, but in 'allegro' or fast speech, nasalization spreads through these segments, leaving them voiceless and prenasalized (Bivin 1986: 102). Stress may affect triggers or blockers of stress; it plays a particularly notable role in the Tupí-Guaraní languages. For example, in Guaraní, a Tupí language of Paraguay, nasal spreading originates from nasal stressed syllables and is blocked by oral stressed syllables. Other languages in which nasal spreading is triggered by a stressed vowel include Ulu Muar Malay (Hendon 1966) and Applecross Gaelic. In the Midwestern variety of American English, nasalization spreads up to and including a stressed syllable but not beyond (Schourup 1973 citing personal communication with Stampe). In Kaiwá, stress affects the degree of nasalization. Bridgeman (1961) notes that in nasal morphemes, nasalization is strongest in stressed syllables and considerably weaker in unstressed positions.

Finally it may be observed that a variable in nasal harmony is the direction of nasal spread. This may be rightward (progressive), leftward (anticipatory) or bidirectional. Each of these is well-attested; however, when spreading is unidirectional, rightward nasalization across syllables is much more common than nasalization to the

left. In spite of this difference in frequency, the direction of spreading is not predictable and must be independently stated.[20]

20 But see Cohn (1993c) for discussion of a general correlation between deletion or effacement of the nasal trigger and directionality of spreading.

2.4.2 The nasal harmony database (condensed version)

i. Vowels (Glottals) Glides Liquids Fricatives Obstruent stops

Language:	Triggers:	Thru:	Dir:	Comments:	Selected Refs:
Barasano (Northern dialect; Tucanoan, Colombia)	Nasal vowels (nasal stops if posited in UR)	V, h	Right	This restrictive right-spreading pattern is quite different from full spreading in the Southern dialect and should be reverified.	Stolte & Stolte 1971; Steriade 1993a
Guahibo (Guahibo-Pamaguan; Colombia, Venezuela)	Nasal stops, Nasal vowels	V, h	Right		Kondo & Kondo 1967
Mixtec (Ayutla dialect; Mixtecan; Mexico)	Nasal stops, Nasal vowels	V, ʔ	Right	The glottal fricative is rare in this dialect.	Pankratz & Pike 1967
Mixtec (Mixtepec dialect; Mixtecan; Mexico)	Nasal stops	V, ʔ	Right	There is no [h] in the language.	Pike & Ibach 1978
Mixtec (Molinos dialect; Mixtecan; Mexico)	Nasal stops	V, h, ʔ	Bidir.	Nasalization is limited to a domain of a disyllabic couplet which forms the nucleus of the phonological word.	Hunter & Pike 1969; Beddor 1983
Mixtec (Silacayoapan dialect; Mixtecan; Mexico)	Nasal stops, Nasal vowels	V, ʔ	Bidir.	Nasal harmony is limited to domain of a disyllabic couplet which forms the nucleus of the phonological word. [h] does not seem to become nasalized.	North & Shields 1977; Marlett 1992

Language:	Triggers:	Thru:	Dir:	Comments:	Selected Refs:
Pame Otomi (Otopamean; Mexico)	Nasal vowels	V, h, ʔ	Right	Gibson's description suggests that nasality spreads through more segments, but examples only show spreading through vowels, glottals (as noted by Schourup).	Gibson 1956; Schourup 1973; Beddor 1983
Sundanese (Hesperonesian; Indonesia)	Nasal stops	V, h, ʔ	Right	[ʔ] is not phonemic. There are interesting complexities with nasal harmony and infixation.	Robins 1953, 1957; Langendoen 1968; Anderson 1972; Howard 1973; Condax et al. 1974; Hart 1981; van der Hulst & Smith 1982; Cohn 1990, 1993a, b, Piggott 1992, Benua 1997; Walker & Pullum 1997
Tinrin (Melanesian)	Nasal stops; Prenasalized stops; Nasal vowels	V	Left	Glottals [h, hw], behave in some ways like voiceless velar continuants.	Osumi 1995

ii. Vowels (Glottals) Glides Liquids Fricatives Obstruent stops

Language:	Triggers:	Thru:	Dir:	Comments:	Selected Refs:
Acehnese (Hesperonesian; Indonesia)	Nasal stop (Nasal V?)	V, j, w, h, ʔ	Right	Triggering segment in penultimate syllable.	Durie 1985
Aguaruna (Jivaroan; Peru)	h̃, placeless coda nasal	V, j, w	Bidir.	[h̃] is in complementary distribution with a velar nasal.	Payne 1974; Bivin 1986; Trigo 1988; Walker & Pullum 1997

Language:	Triggers:	Thru:	Dir:	Comments:	Selected Refs:
Arabela (Zaparoan; Peru)	Nasal stops, h̃	V, j, w	Right	Glottal fricative is nasal in all environments.	Rich 1963; Howard 1973; Beddor 1983; Walker & Pullum 1997
Bariba (Voltaic; Nigeria)	Nasal stops, Nasal vowels	V, j	Left	Spreading seems to be restricted to the syllable.	Welmers 1952; Beddor 1983
Breton (Celtic; France)	Nasal vowels	V, w	Left	No glottals in the language. Patterning of [j] is unclear.	Ternes 1970; Dressler 1972; Schourup 1973; Walker & Pullum 1997
Capanahua (Panoan; Peru)	Nasal stop	V, j, w, h, ʔ	see note:	Nasality spreads to left, but if nasal C is deleted, spreading is bidirectional.	Loos 1969; Halle & Vergnaud 1981; van der Hulst & Smith 1982; Safir 1982; Piggott 1987, 1992; Trigo 1988
Chinantec (Tepetotutla dialect; Chiantecan; Mexico)	Nasal stops, Nasal vowels	V, j, w, weak velar (semi)-cons.	Right	Spreading is syllable-bound.	Westley 1971; Walker & Pullum 1997
Dayak (Kendayan dialect; Indonesian; Borneo)	Nasal stops (?)	V, glottals, glides	Right	Description from Court (1970) citing Dunselman.	Dunselman 1949; Court 1970
Dayak (Land - Bukar Sadong dialect; Hesperonesian; Indonesia)	Nasal stops	V, j, w, h, ʔ	Right	Glottal stop is described by Scott as a 'junction feature'. Glides/glottals block in some words.	Scott 1964; Court 1970; Schourup 1973
Dayak (Land - Mĕntu dialect; Indonesian; Sarawak)	Nasal stops	V, j, w, h, ʔ	Right	Glides/glottals block in some words.	Court 1970

Language:	Triggers:	Thru:	Dir:	Comments:	Selected Refs:
Dayak (Sea dialect; Indonesian; Sarawak)	Nasal stops	V, j, w, glottals (?)	Right		Scott 1957; Kenstowicz & Kisseberth 1979
Konkani (Indo-Iranian; India)	Nasal stops; Nasal vowels	V, j	Left (see note:)	Spreading also to right but just to word-final segments.	Fellbaum 1981; Ghatage 1963; Beddor 1983; Walker & Pullum 1997
Lamani (Indo-Aryan; Gulbarga District, India)	Nasal vowels	V, j, w	Right	Trail is not explicit about the behavior of [h] in nasalization.	Trail 1970
Madurese (Malayo-Polynesian; Indonesia)	Nasal stops	V, j, w, h, ʔ	Right	Glides spread through are not phonemic; phonemic glides are rare. There is an interesting interaction between nasal harmony and reduplication.	A. Stevens 1968, 1985; Mester 1986; McCarthy & Prince 1995
Malay (Johore dialect; Indonesian; Malaysia)	Nasal stops	V, j, w, h, ʔ	Right	Glottal stop is not phonemic.	Dyen 1945; Court 1970; Kenstowicz & Kisseberth 1979; Onn 1980; Pulleyblank 1989; Piggott 1992
Malay (Ulu Muar dialect; Indonesian; Malaysia)	Nasal vowels	V, j, w, h, ʔ	Left	Nasal vowels occur phonemically only in stressed syllables.	Scott 1964; Hendon 1966
Marathi (Indo-Aryan; India)	Nasal stops	V, j, w	Left	Nasalization is limited to the syllable. There is no glottal stop. [h] is described as voiced. Whether [h] can be nasalized is unclear.	Pandharipande 1997
Maxakali (Isolate; Brazil)	Nasal stops	V, j, w, h, ʔ	Bidir.		Gudschinsky et al. 1970; Anderson 1976; Walker & Pullum 1997

Language:	Triggers:	Thru:	Dir:	Comments:	Selected Refs:
Melanau (Mukah dialect; Austronesian; Sarawak)	Nasal stops	V, j, w, h, ʔ	Right		Blust 1988
Orejon (dialect described by Velie & Velie; Tucanoan; Peru)	Nasal vowels	V, j, h	Right	Nasalization is contrastive only in initial syllable. Behavior of glottal stop is unclear.	Velie & Velie 1981; Cole & Kisseberth 1995
Oriya (Colloquial variety; Indo-Aryan; India)	Nasal stops	V, j, w	Bidir.	Nasalization of vocoids occurs under deletion of a nasal stop in colloquial speech.	Patnaik 1984; Piggott 1987
Rejang (Austronesian; South Sumatra)	Nasal stops	V, j, w	Right	Glottal stop blocks nasal spread. Patterning of [h] is unclear.	McGinn 1979; Coady & McGinn 1982
Saramaccan (Surinam)	Nasal stops	V, j, ɲ	Right	Nasality in syllable rhyme spreads across laminal (palatal) sonorants.	Rountree 1972
Seneca (Iroquoian; Canada, USA)	Nasal stops, Nasal vowels	V, glides, glottals	Bidir.	Chafe reports that [sw] does not block spreading. Some complications in left spreading.	Holmer 1952; Chafe 1967; Beddor 1983
Terena/o (Arawakan; Brazil)	First person morpheme	V, j, w, ʔ	Right	Nasalization is morphemic (marks 1st pers). [h, hʲ] pattern as fricatives, not glottals. It is not clear whether /l, r/ block or undergo.	Bendor-Samuel 1960; Leben 1973; Hart 1981; Bivin 1986; Piggott 1987; Cole & Kisseberth 1995
Warao (Isolate; Venezuela; Guyana)	Nasal stops, Nasal vowels	V, j, w, h	Right	There is no phonemic glottal stop in the language.	Osborn 1966; Schourup 1973; Piggott 1987; Piggott 1992
Urak Lawoi' (Hesperonesian; Thailand, Malaysia)	Nasal stops	V, j, w	Right	Trigger must be in the penultimate syllable (stressed). Behavior of [h, ʔ] is not discussed.	Hogan 1988

Language:	Triggers:	Thru:	Dir:	Comments:	Selected Refs:
Urdu (Indo-Iranian; Pakistan, India)	Nasal stops, Nasal vowels	V, j, w, h	Bidir.	There is no phonemic glottal stop in the language.	Hoenigswald 1948; Poser 1982; Walker & Pullum 1997

iii. Vowels (Glottals) Glides Liquids Fricatives Obstruent stops

Language:	Triggers:	Thru:	Dir:	Comments:	Selected Refs:
Edo (Kwa, Nigeria)	Nasal vowels	V, l, r ([+son])	Right	Nasal spreading targets sonorants in suffixes after a nasal stem vowel (glides/ glottals do not occur in relevant affixes).	Aikhionbare 1989
English (Midwestern dialect; Germanic; USA)	Nasal stops	V, j, w, h, l, r	Left	Description from Schourup (1972, 1973) citing Stampe (p.c.). Nasalization spreads only up to a stressed syllable.	Schourup 1972, 1973
Epena Pedee (Saija; Choco; Colombia)	Nasal vowels (Nasal stops if posited in UR)	V, j, w, h, ɾ	Right	The flap undergoes nasalization but the trill blocks. Patterning of glottal stop is unclear.	Harms 1985, 1994; Bivin 1986
Epera (Choco; Panama)	Nasal morpheme	V, glides, glottals, liquids	Right	This describes cross-morpheme spreading. Patterning of voiced fricatives is unclear.	Morris 1977; Bivin 1986
Ewe/Gbe (Kwa; Ghana, Togo, Bénin, Nigeria)	Nasal vowels	j, w, ɥ, l, ɾ, r, ɣ, b	Left	There are no glottals. Spreading is in the syllable. [ɣ, b] alternate with [ŋ, m] and might be treated as sonorants.	Capo 1981
Hindi (Indo-Iranian; India, Pakistan)	Nasal vowels	V, j, w, h, ɽ	Left (bi-dir?)	Nasalization of consonants is supported by nasograph data (M. Ohala 1975).	M. Ohala 1975

Language:	Triggers:	Thru:	Dir:	Comments:	Selected Refs:
Ijo (Kolokuma dialect; Kwa; Nigeria)	Nasal stops, Nasal vowels	V, j, w, ɾ, l	Left	/l/ becomes [n] before nasal vowels. Williamson (1969) reports a similar pattern in Kalabari and Nembe dialects. Patterning of [h] is unclear.	Williamson 1965, 1969b, 1987; Piggott 1992
Isoko (Ozoro dialect; Kwa; Nigeria)	Nasal vowels	j, w, ɾ, ɹ	Left	Spreading appears to be syllable-bound. Patterning of [h] is unclear.	Mafeni 1969
Kayan (Uma Juman dialect; Austronesian; Sarawak)	Nasal stops	V, j, w, h, ʔ, l	Right	Blust notes that it could not be determined whether /r/ permits carry-over of nasalization.	Blust 1977, 1996
Kpelle (Mande; Liberia, Guinea)	Nasal vowels	V, j, l, ɣ	Right	[ɣ] represents a velar resonant.	Welmers 1962; Pulleyblank 1989
Mandan (Siouan, USA)	?	V, w, h, r	?	Description from Schourup (1972) citing Hollow (1970)	Schourup 1972 (citing Hollow 1970)
Spanish (South Castilian dialect; Romance)	Nasal segment	[+son]	Bidir.		Clements 1977; Safir 1982
Tucano (Tucanoan; Colombia)	Nasal morpheme	V, j, w, h, ʔ, r	Right	This pattern occurs in spreading across morphemes (to alternating affixes). [g] also does not block spreading.	West & Welch 1967, 1972; West 1980; Bivin 1986; Trigo 1988, Noske 1995
Tuyuca (Tucanoan; Colombia, Brazil)	Nasal morpheme	V, j, w, h, r	Right	This pattern occurs in spreading across morphemes (to alternating affixes). [g] also does not block spreading.	Barnes & Takagi de Silzer 1976; Bivin 1986; Barnes & Malone 1988; Barnes 1996
Urhobo (Kwa, Nigeria)	Nasal vowels, Nasal stops?	V, j, w, β, ɾ	Left	[β] represents a bilabial frictionless continuant. There are no glottals in the language.	Kelly 1969; Piggott 1992

Language:	Triggers:	Thru:	Dir:	Comments:	Selected Refs:
Yoruba (Oyo - Standard dialect; Kwa; Nigeria)	Nasal vowels	V, j, w, ɾ, l	Left	/l/ becomes [n] before nasal vowels. Nasal spreading appears to be syllable-bound.	Ward 1952; Bamgbose 1966b, 1969; Beddor 1983; Pulleyblank 1989

iv. Vowels (Glottals) Glides Liquids Fricatives Obstruent stops

Language:	Triggers:	Thru:	Dir:	Comments:	Selected Refs:
Ennemor (Semitic; Ethiopia)	Unclear	V, j, w, ʔ, r, β, ʒ	?	Interesting historical basis to nasalization.	Hetzron & Marcos 1966
Itsekeri (Kwa; Nigeria)	Nasal vowels	j, w, ɾ, ɣ	Left	Voiceless fricatives do not undergo. Spreading appears to be syllable bound. There are no glottals in the language	Opubor 1969
Scottish Gaelic (Applecross dialect; Celtic; Scotland)	Nasal vowels (in a stressed syllable)	V, glides, glottals, liquids, frics.	Right (see note:)	Nasalization also extends to onset of the stressed syllable. Mid-high vowels are never nasalized and block spreading.	Ternes 1973, van der Hulst & Smith 1982; Piggott 1992
UMbundu (Benue-Congo; Angola)	Nasal continuant consonants, Nasal vowels	V, j, w, h, l, v	Bidir.	In addition to nasal stops and vowels, Umbundu has /ṽ, l̃, j̃, h̃/. Domain of spreading is complicated — see Schadeberg (1982).	Schadeberg 1982

v. Vowels (Glottals) Glides Liquids Fricatives Obstruent stops

Language:	Triggers:	Thru:	Dir:	Comments:	Selected Refs:
Apinayé (Ge; Brazil)	Nasal vowels	j, r, v, nasal or voiced stops	Bidir.	Spreading is limited to syllable. /j, r, v/ each range between glide, liquid, and fricative constriction. Nasal/ voiced stops are fully nasal in nasal syllables; otherwise they are pre/post-nasalized.	Burgess & Ham 1968; Steriade 1993a
Barasano (Northern dialect; Tucanoan, Colombia)	Nasal vowels	All classes of segs	Left	Nasal spreading to left is syllable-bound. Voiceless stops remain oral.	Stolte & Stolte 1971; Steriade 1993a
Barasano (Southern dialect; Tucanoan, Colombia)	Morpheme-level property (or nasal vowel/ stop)	All segs	Bidir.	Voiceless segments behave transparent.	Smith & Smith 1971; Jones & Jones 1991; Piggott 1992, Rice 1993; Steriade 1993a
Bribri (Chibchan; Costa Rica)	Nasal vowel in a tonic syllable.	All classes of segs	Left	Voiceless obstruents block spreading. Spreading targets atonic syllables.	Constenla 1985
Cabécar (Southern dialect; Chibchan)	Nasal vowels	All classes of segs	Left	Voiceless obstruents block spreading.	Constenla 1985
Cabécar (Northern dialect; Chibchan)	Nasal vowels	All classes of segs	Left	Voiceless obstruents behave transparent to spreading.	Constenla 1985
Cayuvava (Isolate; Bolivia)	Nasal stops, Nasal vowels	All classes of segs	Bidir.	Voiceless obstruents behave transparent. Description is vague concerning domain and nasalization of some intervening consonants.	Key 1961, 1967

Language:	Triggers:	Thru:	Dir:	Comments:	Selected Refs:
Cubeo (Tucanoan; Colombia)	Nasal vowels	All classes of segs	Left	Voiceless stops remain oral. Salser describes this as spreading to onsets; it is unclear whether spreading across syllables takes place.	Salser 1971
Desano (Tucanoan; Colombia, Brazil)	Morpheme-level property (or nasal vowel/ stop)	All segs	Bidir.	Voiceless segments behave transparent.	Kaye 1971; Leben 1973; Miller 1976; Bivin 1986; Steriade 1993a
Epena Pedee (Saija; Choco; Colombia)	Nasal vowels (nasal stops if posited in UR)	All classes of segs	Left	Voiceless stops remain oral; voiceless fricatives are reportedly nasalized. Left spreading is restricted to syllable.	Harms 1985, 1994; Bivin 1986
Epera (Choco; Panama)	Nasal vowels (?)	All classes of segs	Right	This for morpheme-internal spreading. Voiceless obstruents block in 'normal' speech; but they behave transparent in fast speech.	Morris 1977; Bivin 1986
Gbeya (Adamawa-Eastern; Central African Republic)	Nasal vowels	All classes of segs	Right	Voiceless stops remain oral. Behavior of fricatives and voiced stops is unclear.	Samarin 1966; Beddor 1983; Steriade 1993a
Gokana (Benue-Congo; Nigeria)	Nasal stops, Nasal vowels	All classes of segs	Right	Voiceless segments do not occur in the environment for nasalization (they occur only initially). There are no glottals.	Hyman 1982; Piggott 1987; Steriade 1993a
Guanano (Tucanoan; Colombia)	Morpheme-level property (or nasal vowel/ stop)	All segs	Bidir.	Voiceless segments behave transparent.	Waltz & Waltz 1967, 1972; Bivin 1986

Language:	Triggers:	Thru:	Dir:	Comments:	Selected Refs:
Guaraní (Tupí; Paraguay, Brazil, Argentina)	Nasal vowel in a stressed syllable	All segs	Bidir.	Voiceless segments behave transparent. Stressed syllables containing an oral vowel block spreading.	Gregores & Suárez 1967; Rivas 1974, 1975 (for others see chapter 4)
Guaymi (Panama)	Near past completed action morpheme	All classes of segs	Right	Nasalization marks near past completed action in class II verbs. Voiceless consonants and back vowels block. Voiced obstruents are variable in their behavior.	Kopesec & Kopesec 1974, 1975; Bivin 1986
Igbo (Central, Ohuhu dialect; Igbo; Nigeria)	Syllable-level property (or nasal stops and nasal vowels)	All classes of segs	Bidir.	With the exception of voiceless stops, all segments are reported to have nasal alternants, including fricatives.	Green & Igwe 1963 Williamson 1969a; Clark 1990;
Icua Tupí (Tupí-Guaraní; Brazil)	Morpheme-level property (or nasal vowel/ stop)	All classes of segs	Bidir.	Description is only tentative: based on speakers. Realization of /h/ and /r/ in a nasal context is unclear.	Abrahamson 1968; Bivin 1986
Kaiwá (Tupí-Guaraní; Brazil)	Morpheme-level property (or nasal vowel/ stop)	V, glides, glottals, liquids, frics., stops	Bidir.	Glottal stops block nasal spread in slow speech. Realization of glides, liquids, and fricatives in nasal contexts is unclear. Voiceless stops are transparent.	Bridgeman 1961; Harrison & Taylor 1971
Mixtec (Atatlahuca dialect; Mixtecan; Mexico)	Morpheme level property or last vowel	All classes of segs	Left	Voiceless obstruents block spreading. Voiced segments become nasalized.	Alexander 1980; Marlett 1992
Mixtec (Coatzospan dialect; Mixtecan; Mexico)	Second person familiar morpheme	All classes of segs	Left	Voiceless obstruents generally block spreading. Voiced obstruents behave transparent.	Pike & Small 1974; Piggott 1992; Gerfen 1996

Language:	Triggers:	Thru:	Dir:	Comments:	Selected Refs:
Mixtec (Ocotepec dialect; Mixtecan; Mexico)	Morpheme level property or last vowel	All classes of segs	Left	Voiceless obstruents behave transparent to spreading. Voiced segments become nasalized	Marlett 1992
Orejon (dialect described by Arnaiz; Tucanoan; Peru)	Morpheme-level property or first syllable	All classes of segs	Right	Description from Pulleyblank citing Arnaiz. Voiceless obstruents block spreading. Voiced obstruents are nasalized.	Arnaiz 1988; Pulleyblank 1989
Parintintin (Tupí-Guaraní; Brazil)	Nasal vowels (or morpheme-level property)	All classes of segs	?	Voiceless obstruents block spreading. Voiced obstruents are nasalized.	Pease & Betts 1971; Hart 1981; Bivin 1986
Shiriana (Shirianan; Venezuela, Brazil)	Nasal vowel (or foot-level property)	All classes of segs	Bidir.	Nasal spreading is bounded by the foot. It is unclear whether all obstruents behave transparent or whether some become nasalized.	Migliazza & Grimes 1961; Beddor 1983
Siriano (Tucanoan, Colombia, Brazil)	Morpheme-level property (or nasal vowel/ stop)	All segs	Bidir.	Voiceless segments behave transparent.	Bivin 1986 (citing Malone et al. 1985)
Tatuyo (Tucanoan; Colombia)	Morpheme-level property (or nasal vowel/ stop)	All segs	Bidir.	Voiceless segments behave transparent.	Gomez-Imbert 1980; Steriade 1993a
Tucano (Tucanoan; Colombia)	Morpheme-level property (or nasal vowel/ stop)	All segs	Bidir.	Voiceless segments behave transparent. This pattern occurs in morpheme-internal spreading.	West & Welch 1967, 1972; West 1980; Bivin 1986; Trigo 1988, Noske 1995

Language:	Triggers:	Thru:	Dir:	Comments:	Selected Refs:
Tuyuca (Tucanoan; Colombia, Brazil)	Morpheme-level property (or nasal vowel/ stop)	All segs	Bidir.	Voiceless segments behave transparent. This pattern occurs in morpheme-internal spreading.	Barnes & Takagi de Silzer 1976; Bivin 1986; Barnes & Malone 1988; Barnes 1996