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A SPLIT ANALYSIS OF NASAL HARMONY IN MBYA

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ABSTRACT

This paper proposes an optimality theoretic analysis of nasal harmony in Mbya Guarani. I propose that this phenomenon is best understood as the product of two distinct phenomena: (i) nasal harmony between adjacent syllable nuclei and (ii) nasal coarticulation from a vowel to an adjacent consonant edge.

KEYWORDS: Guarani, nasal harmony, Optimality Theory.

UMA ANÁLISE DUPLA DA HARMONIA NASAL EM GUARANI MBYA

RESUMO

Apresentamos uma análise da harmonia nasal em Guarani Mbyá, no quadro da Teoria da Otimalidade. Propomos que este fenômeno é o resultado de dois processos distintos: (i) a harmonia nasal entre núcleos de sílabas adjacentes e (ii) a coarticulação nasal entre uma vogal e uma consoante adjacente.

PALAVRAS-CHAVE: Guarani, harmonia nasal, Teoria da Otimalidade.

1. INTRODUCTION

This paper proposes an optimality theoretic analysis of nasal harmony in Mbya Guarani using secondary data, from Guedes (1983) and Dooley (2006). Mbya is a Guarani language of the Tupi Guarani family, spoken in Argentina, Brazil and Paraguay. As in Paraguayan Guarani (Gregores and Suárez, 1967; Lunt, 1973; Rivas, 1975), there appears to be two forms of nasal harmony in Mbya: (i) a fully productive process of regressive nasalization triggered by rootfinal stressed nasal vowels, that spans the whole root and its prefixes, and (ii) a semi-productive process of progressive nasalization from root-final stressed vowels to subsequent suffixes. In addition, progressive nasal harmony is also attested at the boundary between a nasal root and an oral root in compounds and incorporation, through the prenasalization of the onset of the oral root (Dooley, 1984).

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I propose that nasal harmony in Mbya is best understood as the product of two distinct mechanisms: (i) nasal harmony between adjacent syllable nuclei and (ii) nasal coarticulation from a vowel to an adjacent consonant edge. The proposed analysis, which is laid out in Optimality Theory (OT), is inspired by the work of Piggott and van der Hulst (1997).

One of the advantages of the split analysis of nasal harmony is that it accounts for the transparency of voiceless stops in regressive nasal harmony without resorting to a form of opacity (*pace* Walker, 1998). Indeed, I argue that Walker's (1998) factorial typology of blocking and transparent segments is preserved in the split analysis.

In addition, the analysis explains why voiceless stops in the input are transparent in regressive nasalization while they can surface as prenasalized stops or even fully nasal consonants in progressive nasalization.

Finally, the split analysis also solves a puzzle formulated in Steriade's (1993) discussion of prenasalized consonants. Steriade observed that prenasalized stops are only attested in languages with non-iterative nasal harmony. However, Steriade identified two hitherto unexplained exceptions to this generalization: Guarani and Terena. I argue that the coarticulatory analysis of prenasalization that is proposed in the split analysis explains away Guarani exceptionality. Crucially, Steriade's insight is vindicated, since prenasalized stops in Guarani are not attested in the span of regressive harmony, which is truly iterative.

The paper is structured as follows. Sections 2 and 3 introduce relevant aspects of the phonology of Mbya, and describe the patterns of nasal harmony attested in the language. In section 4, I discuss the representation of prenasalized stops. The core of the analysis is presented in section 5. In section 6, I discuss some typological consequences of the analysis. Section 7 concludes.

2. SEGMENTAL INVENTORY, SYLLABLE STRUCTURE AND STRESS

2.1. Segmental inventory

The following tables present the segmental inventory of Mbya. Note that relations of allophony are not represented in the table.

Table 1: consonants

	labial	alveolar	palatal	velar	labialized-velar	glotal
voiceless stop	p	t		k	kʷ	ʔ
voiced stop					gʷ	
voiceless affricate			ʧ			
voiced affricate			ʤ			
prenazalized stop	ᵐb	ⁿd		ᵑg	ᵑgʷ	
nasal	m	n	ɲ	ŋ	ŋʷ	
fricative	β, v	(s)				h
approximants	w/w̃	r/r̃				

Table 2: vowels

	+ back	+ front
+ high	ɨ/ɨ̃ - u/ũ	i/ĩ
- high -low	o/õ	e/ẽ
+ low	a/ã	

2.2. Syllable structure and stress

Syllable structure Only V and CV syllables are attested in Mbya (in section 5, I will argue that prenasalized stops are complex segments rather than consonant clusters). In addition, there are instances of hiatus:

(1)	aɨˈvu	*speech*

Stress. In words without suffixes, stress usually falls on the last syllable of the root, and more rarely on the penultimate syllable:

(2)	kovaˈʔe	*this*
	oˈɔ	*house*
	põˈɾã	*beautiful*
(3)	ˈara	*day*
	ɨˈvɨɾɨ	*near*

Some suffixes are lexically stressed, in which case the main stress falls on the rightmost suffix that is lexically specified for stress, and stress on the root is demoted to secondary stress (Guedes, 1983):

(4)	ʧe+ˈro	*my house*
	ʧe+ˌro+ˈɾã	*my future house*
	ʧe+ˌro+ˈɾã+pɨ	*in my future house*

3. DISTRIBUTION OF NASAL FEATURES AND NASAL HARMONY

The main pattern of nasal harmony in Mbya can be summarized as follows:

- The domain of nasal harmony is the root plus its prefixes.
- A [root+prefixes] is either oral or nasal, except in the case of prenasalized stops, which are preceded by nasal material and followed by oral material.
- All segments that occur inside a nasal root are nasal, except voiceless stops and voiceless affricates.
- All segments that occur inside an oral root are oral.

In addition, there is a second pattern of nasal harmony which consists in sandhi nasalization at the boundary between roots or between a root and its first suffix. In the rest of this section, I describe both patterns of nasal harmony in more details.

3.1. Root internal nasality

3.1.1. Constraints on the distribution of nasality root internally

The distribution of nasality inside Mbya roots depends on the nasal or oral quality of the stressed vowel (syllable nucleus) of the root. Consider first roots with nasal stress, i.e. roots with a stressed nasal vowel. All such roots obey the following generalizations:

(5) Roots with nasal stress:
1.All vowels in the root are nasal.
2.No oral voiced stop or voiced affricate is attested.
3.No prenasalized stop is attested.
4.Voiced approximants and fricatives are attested and nasalized.
5.Voiceless stops and affricates are attested and remain oral.
6.Nasal consonants are attested.

1. All the preceding vowels are nasal. No oral vowel is attested. Therefore, (6) but not (7) is a possible word:

(6) ãˈkã *head*
(7) *aˈkã

2. Mbya has one glided voiced stop /gʷ/, and one voiced affricate, /ʤ/. Neither one is attested in a root with nasal stress:

(8) ŋʷãr̃ã nominalizer
(9) *gʷãr̃ã
(10) ɲãr̃õ *angry*
(11) *ʤãr̃õ

3. Prenasalized stops are only attested when they are followed by an oral vowel; in particular, they are never attested in roots with nasal stress:

(12) kãˈᵐbɨ *milk*
(13) *kãˈᵐbɨ̃

4. Voiced approximants and fricatives are attested in roots with nasal stress, but they are always nasalized:

(14) kɨ̃ˈṽõ *there*
(15) *kɨ̃võ
(16) pãɨ̃ˈr̃ã *to tinge*
(17) *pãˈrã

5. Voiceless stops and voiceless affricates are attested in roots with nasal stress, and they are not nasalized.

(18) ˈtɨ̃ *to plant*
(19) ʧãˈkã *wood*

Note that the voiceless fricative /s/ of Mbya seems to be attested only in one word, *sapukai* (‘to shout’), which may have been borrowed from Paraguayan Guarani.

Let us now consider roots with oral stress. These roots can be put in two different groups, depending on whether they include a prenasal stop or not.

(20) Roots with oral stress that do not include a prenasalized stop:
1. All vowels in the root are oral.
2. No nasal consonant is attested.
3. Voiced fricatives and approximants are attested and oral.
4. Voiceless stops, affricates and fricatives are attested and oral.
5. Voiced stops and affricates are attested and oral.

1. All the vowels in the root are oral:

(21) taˈpe *path*
(22) *tãˈpe

2. No nasal consonant is attested:

(23) taˈta *fire*
(24) *naˈta

3. Voiced fricatives and approximants are attested, and are always oral:

(25) vaˈi *evil*
(26) *ṽaˈi
(27) ˈru *path*
(28) *ˈr̃u

4. Voiceless stops, affricates and fricatives are attested and oral:

(29) puˈka *laugh*
tʃiˈvi *cat*
sapuˈkaʲ *to shout*

5. Voiced stops and affricates are attested and oral:

(30) gʷaˈki *rat*
dʒaˈtʃɨ *moon*

Let us abstract away from the complications induced by prenasalized stops for a moment. We observe that a stressed nasal vowel induces the nasalization of all preceding vowels and consonants, with the exception of voiceless stops and affricates, which are transparent to nasal harmony. Conversely, orality of the last vowel of a root prevents any manifestation of nasality on preceding vowels and consonants – vowels and approximants are oral rather than nasal, and nasal consonants are unattested. Let us call 'nasal span' the part of a root that is subject to nasal harmony, and let us call 'oral span' the part of a root which is subject to oral harmony.

Roots with oral stress and that include a prenasalized stop are more complex than other roots with respect to nasal harmony. These roots obey the following generalizations:

(31) Roots with oral stress that include a prenasalized stop:

1.There is only one prenasalized stop in the root (call it ND).

2.There is a nasal span preceding ND:
(a)All vowels are nasal.
(b)No oral voiced stop or voiced affricate is attested.
(c)No prenasalized stop is attested.
(d)Voiced fricatives and approximants are attested and nasalized.
(e)Voiceless stops and affricates are attested and remain oral.
(f)Nasal consonants are attested.

3.There is an oral span following ND:
(a)All vowels in the root are oral.
(b)No nasal consonant (or prenasalized stop) is attested.
(c)Voiced fricatives and approximants are attested and oral.
(d)Voiceless stops, affricates and fricatives are attested and oral.
(e)Voiced stops and affricates are attested and oral.

In short, when a root contains a prenasalized stop ND, ND acts as a buffer between a preceding nasal span and a following oral span. The following examples show that root internal ND is preceded by a nasal span:

a. All vowels following ND are oral:

(32) ᵐbuˈku *long*
*ᵐbũkˈũ

b. No nasal consonant is attested after ND:

(33) ᵐbuˈku *long*
*ᵐbuˈŋu

c. Voiced approximants are attested and oral after ND:

(34) ᵐboˈvy *few*
ᵐboriaˈu *poor*

d. Voiceless stops, affricates and fricatives are attested and oral after ND:

(35) ᵐboaˈpɨ *three*
ᵐboˈʧɨ *angry*

e. Voiced stops and affricates are attested and oral after ND:

(36) ᵐbeˈgʷe *secretly*
ᵐbeˈʤu *corn bread*

The next examples show that the part of the root that precedes a prenasalized stop acts as a nasal span:

a. All vowels are nasal before ND:

(37) kãˈᵐbɨ *milk*
*kaˈᵐbɨ

b. No oral voiced stop or voiced affricate is attested before ND:

(38) ŋʷẽˈᵐbe a type of plant
*gʷẽˈᵐbe

c. No prenasalized stop is attested before ND:

(39) mõˈⁿda *to steal*
*ᵐbõˈⁿda

d. Voiced fricatives and approximants are attested and nasalized before ND:

(40) ãr̃ãˈⁿdu *knowledge*

e. Voiceless stops and affricates are attested and remain oral before ND:

(41) tãtãẽˈⁿdɨ *lamp*

f. Nasal consonants are attested before ND:

(42) mãⁿdiˈʔo *yuka*

These facts show that it is not possible to analyze nasal harmony in Mbya as wholesale nasalization of a root as nasal or oral. Indeed, whereas roots that contain no prenasalized stops are harmonic (modulo the presence of transparent voiceless stops and affricates in nasal roots), roots that include prenasalized stops are systematically disharmonic.

One may be tempted to reduce the disharmony induced by prenasalized stops to the directionality of nasal spreading. According to this view, a nasal vowel or a nasal consonant would spread nasality leftward, ignoring transparent segments (voiceless stops and affricates). This would explain the fact that roots with nasal stress are completely nasal (transparent segments aside, of course), while roots that contain a prenasalized stop are nasal to the left of this stop, and oral to its right, the closure of the prenasalized stop acting as a nasal trigger. This analysis would also explain the fact all disharmonic roots in Mbya are partitioned in a leftward nasal span and a rightward oral span, with a nasal trigger at the boundary. However, this analysis would fail to explain why all disharmonic roots have a prenasalized stop at the boundary between their nasal span and their oral span. More precisely, it would predict that any nasal trigger (including nasal vowels and thoroughly nasal consonants) could occur at the boundary between the leftward nasal span and the rightward oral span.

How can we explain the fact that there is always a prenasalized stop at the boundary between a nasal span and an oral span? Assume that an agreement constraint forces adjacent syllable nuclei to have the same feature specification for nasality. Assume also that some set of higher ranked constraints prevent a nasal segment from being adjacent to an oral segment. Since prenasalized stops have both a nasal edge to their left and an oral edge to their right, they would allow this constraint to be satisfied while being followed by oral segments. Other nasal segments would not satisfy this constraint and therefore would not be allowed to lie at the boundary between a nasal span and an oral span. Note that according to such an analysis, nasal harmony in Mbya is the result of two distinct processes: a first process of nasal harmony between syllable nuclei, and a second process of nasal coarticulation between adjacent vowels and consonant edges. An analysis of nasal harmony in Mbya along these lines is proposed in sections 5 and 6. Since the concept of CV and VC nasal coarticulation is at the heart of the analysis, it is important to pay attention to the distribution of nasality in pairs of adjacent consonants and vowels.

3.1.2. A summary of restrictions on consonant-vowel adjacency

The following observations summarize the distribution of consonants relative to the nasality of their environment.

1. Voiceless stops (T): attested between two nasal vowels, between two oral vowels, or word initially before either:

(43) ṼTṼ, VTV, #TṼ, #TV

2. Voiced stop /g^w/: only attested between two oral vowels or word initially before an oral vowel:

(44) Vg^{w}V, #g^{w}V

3. Voiceless affricate /tʃ/: attested between two nasal vowels, between two oral vowels, or word initially before either:

(45) ṼʧṼ, VʧV, #ʧṼ, #ʧV

4. Voiced affricate /ʤ/: attested between two oral vowels or word initially before an oral vowel:

(46) VʤV, #ʤV

5. Voiced approximants (L): attested between two nasal vowels, between two oral vowels, or word initially before either; nasalized when adjacent to a nasal vowel:

(47) ṼL̃Ṽ, VLV, #L̃Ṽ, #LV

6. Nasal consonants (N): attested between two nasal vowels or word initially before a nasal vowel:

(48) ṼNṼ, #NṼ

7. Prenasalized stops (ND): only attested at the boundary between a preceding nasal vowel and a following oral vowel, or word initially followed by an oral vowel:

(49) ṼNDV, #NDV

This overview shows that the set of consonants of Mbya can be partitioned into five classes:

- The first group includes voiceless obstruents. They attested between two nasal vowels, between two oral vowels, or word initially before either. Since they are attested between two oral vowels, they do not trigger nasalization. However, although they are attested between two nasal vowels, they are not attested at the boundary between a nasal span and an oral span. Hence, they do not block nasal harmony, but they are not affected by it either. They are 'transparent'.

- The second group includes voiced obstruents. They are only attested between two oral vowels or word initially before an oral vowel. In other words, they are attested neither inside a nasal span, nor at the boundary between a nasal span and an oral span. They do not block nasal harmony, but are not transparent to it either.

- The third group includes approximants. They are attested between two nasal vowels, between two oral vowels, or they can be used word initially before either. But when they are adjacent to at least one nasal vowel, they are nasalized. Hence, these consonants do not block nasal harmony, but they undergo it. They are 'undergoers'.

- The fourth group includes nasal consonants. They are only attested between two nasal vowels or word initially before a nasal vowel. A way to understand this restriction is that they trigger the nasalization of adjacent vowels.

- The last group includes prenasalized stops. They are only attested at the boundary between a preceding nasal vowel and a following oral vowel, or word initially followed by an oral vowel. They are the only segments that can occur at the boundary between a nasal span and an oral span. One way to make sense of their distribution is to assume that their nasal closure (to the left) induces the nasalization of preceding segments, whereas their oral release (to the right) is compatible with adjacent oral segments.

Let us summarize these observations. Firstly, some but not all oral consonants can occur adjacent to a nasal vowel. Namely, voiceless oral consonants (stops and affricates) can occur adjacent to a nasal vowel, while voiced oral consonants (the stop /gʷ/, approximants, and the right edge of prenasalized stops) cannot. Approximants must be nasalized when they are adjacent to a nasal vowel while /gʷ/ just cannot be adjacent to a nasal vowel. Secondly, nasal consonants cannot be adjacent to oral vowels. Finally, only prenasalized stops cannot occur at the boundary between an oral span and a nasal span.

The facts suggests that CV or VC sequences that are disharmonic with respect to nasality are marked in Mbya. In particular, disharmonic VC or CV sequences are not attested when C is voiced. Nasal consonants are only attested adjacent to nasal vowels, and voiced oral consonants are only attested adjacent to oral vowels. The only exceptions to these generalizations are voiceless stops and affricates, which are transparent to nasal harmony.

3.2. Nasality in prefixes

Whereas root internal nasal harmony can only be observed indirectly, through lexical restrictions on the relative distributions of nasal and oral segments, nasal harmony can be observed directly in prefixes, through phonological alternations. In a nutshell, a prefix is nasalized when the first segment of the root or of the following prefix is nasal, as specified in the following entry:

(50) Nasality in prefixes:
1.Oral vowels are nasalized inside a nasal span.
2.Voiced fricatives and approximants (r, ß, v, w) are nasalized inside a nasal span.
3.The voiced stop /gʷ/ in oral spans alternates with /ŋʷ/ in nasal spans.
4.The voiced affricate /ʤ/ in oral spans alternates with /ɲ/ in nasal spans.
5.Prenasalized stops in oral spans alternate with the homorganic nasal consonants in nasal spans.

The following examples illustrate these generalizations:

1. Oral vowels are nasalized inside a nasal span:

(51) ʧe+ro *My house*
(52) ʧẽ+ᵐbaraka *My guitar*

2. Voiced fricatives and approximants (r, ß, v, w) are nasalized inside a nasal span:

(53) oro+eˈʧa *I see you*
õɾ̃õ+mãˈʔẽ *I watch you*

3. The voiced stop /gʷ/ in oral spans alternates with /ŋʷ/ in nasal spans:

(54) o+guero+aɨˈwu *She had a conversation with her*
õ+ŋʷẽɾ̃õ+ˈɲã *He made it run*

4. The voiced affricate /ʤ/ in oral spans alternates with /ɲ/ in nasal spans:

(55) o+ʤe+eˈʧa *She saw herself*
õ+ɲẽ+mãˈʔẽ *She watched herself*

5. Prenasalized stops in oral spans alternate with the homorganic nasal consonants in nasal spans:

(56) ɲãⁿde+reko *Our way of life*
ɲãnẽ+ᵐbaraˈka *Our guitar*

In sum, all voiced segments undergo nasal harmony, i.e. they are nasalized when they occur inside a nasal span. Approximants and fricatives can be nasalized without any other change of features:

(57) v → ṽ, β → β̃, w → w̃, r → r̃

However, the voiced stop /gʷ/ and the voiced affricate /ʤ/ cannot be nasalized without losing their obstruency. They are then realized as homorganic nasal consonants:

(58) gʷ → ŋʷ, ʤ → ɲ

Prenasalized stops also undergo nasalization. As expected, their voiced obstruent release is nasalized and the stop surfaces as the homorganic nasal:

(59) ᵐb → m, ⁿd → n, ᵑg → ŋ

Voiceless obstruents are transparent:

(60) p, t, k, kʷ, ʧ

The fricative /s/ is only attested in one word ([sapu'kaʲ], ‘shout’), which may have been from Paraguayan Guarani (Dooley (2006) lists the form [ʤapu'kaʲ] instead). Glottal consonants (stop /ʔ/ and fricative /h/) have a special status. As expected, they do not block nasalization. It is not clear whether they should be analyzed as transparent segments or as undergoers, since it is difficult to perceive nasality on such segments. In glottal stops, the closure of the vocal tract below the velar opening prevents any nasal airflow, and therefore any perceptual correlates of a lowered velum. As for glottal fricatives, the fact that they are unvoiced make it difficult to perceive their possible nasalization without nasal airflow measurement. Nevertheless, Walker (1998) argued that glottals usually pattern with voicoids in nasal harmony cross-linguistically, i.e. they are less liable to block nasal harmony than any other consonant. For this reason, one may assume that they undergo nasal harmony in Mbya.

These generalizations are summarized in the following table (leaving aside glottal segments):

Voiceless stops	p, t, k, kʷ	transparent
Voiceless affricate	ʧ	transparent
Voiced stop	gʷ	undergoer
Voiced affricate	gʷ	undergoer
Approximants	w, r	undergoer
Fricatives	v ~ β	undergoer
Prenasalized stops	ᵐb, ⁿd, ᵑg, ᵑgʷ	trigger/undergoer
Nasal consonants	m, n, ɲ, ᵑg	trigger

3.3. Nasality in suffixes

Suffixes do not appear to trigger nasalization of the preceding root or of adjacent suffixes (Dooley, 1984). However, some suffixes are realized with a prenasalized onset when they follow a root-final nasal segment, and with an oral onset when they follow a root-final oral segment:

(61)	ava+ˈkʷe	*Men*
	kũɲã+ˈᵑgʷe	*Women*
	o+eʧa+ˈpa	*She saw them all*
	õ+mãnõ+ˈᵐba	*They all died*

In addition, the oral suffixes *-py* and *-'i* are thoroughly nasalized when they follow a rootfinal nasal segment. This form of wholesale nasalization is unattested with other suffixes:

(62)	tekoa+py	*In the village*
	tẽtã+mɨ̃	*In the city*

(63)	ava+ʔi	*Boy*
	mĩtã+ʔĩ	*Small child*

In sum, putting aside the idiosyncratic alternation attested with these two suffixes, nasal harmony in suffixes is restricted to prenasalization of the left boundary after a root-final nasal segment. In the next subsection, I will argue that this is a particular instance of a more general phenomenon of sandhi prenasalization.

3.4. Sandhi prenasalization

In subsections 3.1 and 3.2, I described a form of nasal harmony that occurs in a domain consisting of a root and its prefixes. This form of harmony is directional, all of its targets occurring to the left of the trigger. In subsection 3.3, I discussed a different form of harmony, which occurs at the boundary between a root and its first suffix, and which goes from left to right. This second form of nasalization is actually not restricted to suffixes. In complex words formed by composition or incorporation, the first segment of the second root may be prenasalized, when preceded by a root-final nasal segment:

(64)	akã	'head'
	ka	'hit'
	ãkã+ᵑga	'head-hitting'

(65)	ãpɨ̃ĩ	'nose'
	kʷa	'hole'
	ãp,ɨ̃ĩ+ᵑgʷa	'nostril'

(66)	tɨ	'plantation'
	takʷa	'taquara'
	r̃ẽʔẽ	'sweet'
	tãkʷã+r̃ẽʔẽ+ⁿdɨ	'sugar-cane plantation'

Note that this type of allomorphy is restricted to voiceless stops (putting aside glottal stops) and voiceless affricates. The attested alternations are the following:

(67) p ~ ᵐb, t ~ ⁿd, k ~ ᵑg, kʷ ~ ᵑgʷ, ʧ ~ ⁿd

Moreover, not all roots are affected. Firstly, no roots that include a nasal vowel undergo this allomorphy:

(68)	akã	'head'
	pɨtã	'read'
	ãkã+pɨ̃tã	'read-head'
	*ãkã+ᵐbɨ̃tã	
	*ãkã+mɨ̃tã	

This is expected, since prenasalized stops are not attested inside the nasal span of a nasal vowel. Note that the fact that voiceless stops do not alternate with fully nasal consonants in this context (e.g. the fact that *ãkã+mɨ̃tã is unattested, as illustrated in (68)) suggests that prenasalization of a voiceless stop incurs less faithfulness violations than wholesale nasalization of a voiceless stop. In other words, a voiceless stop and the homorganic prenasalized stop are more similar than a voiceless stop and the homorganic nasal consonant, and while the grammar of Mbya allows alternations between the first pairs of segments, it prohibits alternations between the second pairs.

Let us summarize the findings of section 3. The most productive form of nasal harmony in Mbya occurs in a domain that consists of a root and its prefixes, as observed in Paraguayan Guarani (see a.o. Gregores and Suárez, 1967; Lunt, 1973; Rivas, 1975; Walker, 1998). Rightward nasal spreading is not fully productive, and with two documented exceptions, it is limited to prenasalization of voiceless consonants at the boundary between a root and its first suffix, or two roots in a compound or an incorporation structure. In section 4, I propose that prenasalization of voiceless consonants is due to nasal coarticulation between vowel and consonants, which is captured by a non-directional agreement constraint that penalizes sequences of adjacent vowels and consonant edges that do not share the same specification of the [nasal] feature. Nasal coarticulation will in turn be integrated in an account of nasal harmony in roots and their prefixes. An essential component of this analysis will be the adoption of a representation of prenasalized stops following Steriade (1993), to which I now turn.

4. PRENASALIZED STOPS

4.1. Prenasalized stops as segments

In this subsection, I argue that NC sequences in Mbya are segments and not clusters. Riehl (2008) demonstrates that languages differ with respect to the realization of nasal/obstruent (NC) sequences as segments or as clusters of segments. At one end of the spectrum is English, where NC sequences are realized as clusters. In English, NC sequences never violate the sonority sequencing principle (SSP): they are attested word finally or word medially across syllable boundaries, but not word initially. In this respect, they pattern like other clusters of decreasing sonority, such as /lt/. In addition, some NC sequences of English are attested across morpheme boundaries (eg. ‘untenable’), in which case they form a cluster whose two segments belong to different morphemes. Finally, the nasal and obstruent parts of NC sequences in English are independently attested. For examples, in the two phonemes /n/ and /d/ that make up the sequence /nd/ in English occur independently of one another in a variety of lexical entries. At the other end of the spectrum are languages like Fijian, which Riehl argues has NC sequences that are segments with a nasal closure and a non-nasal release. Firstly, although NC sequences in Fijian always have a voiced release, the corresponding voiced stops are unattested outside of NC sequences. Secondly, although Fijian has clusters, these are generally not attested in word initial position, contrary to simple segments and prenasalized stops. Finally, NC sequences are attested word medially, although closed syllables are otherwise unattested in Fijian, which suggests that word-medial NC clusters are parsed as onsets. In this context, analyzing NC sequences as clusters would violate the SSP.

Using Riehl’s criteria, one can argue that Mbya prenasalized stops are segments rather than clusters. First, consider the inventory of prenasalized stops:

(69) ᵐb, ⁿd, ᵑg, ᵑgʷ

Aside from /gw/, the voiced stop corresponding to the release of these segments are not independently attested in Mbya, which suggests that the prenasalized stops are not clusters of independent segments.

Secondly, Mbya prenasalized stops would violate the SSP if they were analyzed as clusters. Prenasalized stops and affricates are the only attested CC sequences in the language. Both are attested word initially, where they have to be syllabified as onsets:

(70) mbɨa (‘many people in the same place’)
(71) ʧipa (a kind of bread)

In this position, if prenasalized stops were analyzed as clusters, they would violate the SSP. Consequently, the existence of NC clusters in word initial position should entail the existence of less marked clusters such as /tr/. The absence of such clusters suggests that NC sequences are best analyzed as segments.

Finally, NC sequences in Mbya are attested word-medially, as illustrated in the following example:

(72) kã^{m}bɨ

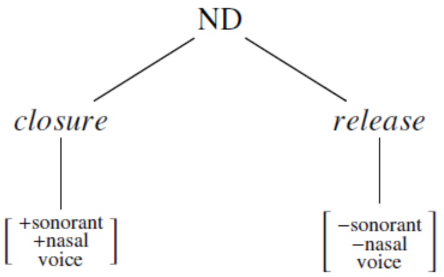
If NC sequences were to be analyzed as clusters, the SSP would enforce a heterosyllabic analysis of the cluster, with the nasal in coda and the voiced stop in onset. However, there are no independently attested closed syllable in Mbya, although the segmental inventory of the language contains consonants of high sonority that could be parsed as codas (such as /r/).

In sum, prenasalized stops are best analyzed as segments with a nasal closure and an oral release.

4.2. Representation of prenasalized stops

Steriade (1993) argues that the phonological representation of consonants consists of a sequence of aperture positions, which serve as an anchor for segmental features. Plosives are represented as sequences of two aperture positions, closure and release, whereas continuants are represented with one aperture position only. This allows us to represent prenasalized stops as segments with a nasal closure and an oral release. I assume that nasality is represented as a binary feature This goes contrary to Steriade (1993, 1995), who argued that nasality should be represented as a privative feature, in order to account for the putative absence of processes of [-nasal] assimilation and dissimilation cross-linguistically. *Pace* Steriade, the use of a [-nasal] feature will be crucial in deriving the transparency of voiceless stops in nasal harmony. Note that it has already been argued that the use of a binary nasal feature is necessary to account for nasal harmony in Guarani (see van der Hulst and Smith, 1982). Furthermore, it is not clear that all analyses of nasal harmony in OT that make use of a privative [nasal] feature are more restrictive than analyses that make use of a binary feature. Indeed, Honeybone (2006) observed that the use of privative [F] features to avoid the generation of [-F] harmony is trumped by the use of Agree([F]) constraints in conjunction with Ident-D([F]) constraints relativized to a domain D, allowing rankings that generate the equivalent of [-nasal] harmony.

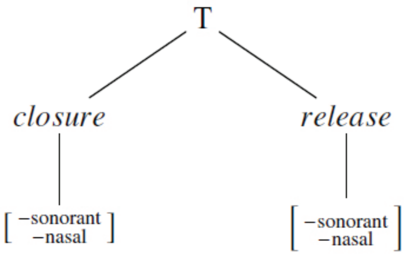
(73) Representation of prenasalized stops:



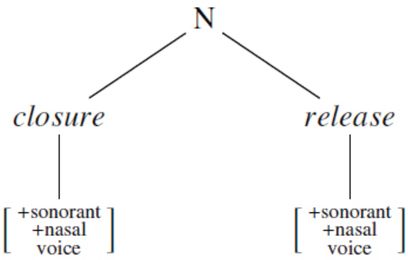
One of the advantages of this representation of prenasalized stops is that it predicts that continuants and unreleased stops, which have only one aperture position, are homogeneously nasal or oral. They cannot be pre- or postnasal.

The use of two aperture positions also allows us to account for the complex association of prenasalized stops with [sonorant] and [voice] features, as illustrated in the following examples:

(74) Voiceless stops:



(75) Nasal consonants:



In the rest of this paper, faithfulness violations triggered by mappings between nasal and oral consonants will make reference to the following constraints:

(76) Ident([voice]): Let *x* be a segment in the input and *y* its correspondent in the output; *x* is linked to [voice] if and only if *y* is linked to [voice].

(77) Ident([-son]): Let *x* be a segment in the input and *y* its correspondent in the output; *x* is linked to [-sonorant] if and only if *y* is linked to [-sonorant].

(78) Ident([+son]): Let *x* be a segment in the input and *y* its correspondent in the output; *x* is linked to [+sonorant] if and only if *y* is linked to [+sonorant].

These constraints favor feature preservation at the segmental level. Therefore, since sonorancy is preserved in the mapping from a voiceless stop in the input, to the release of a prenasalized stop in output, this mapping does not violate Ident([-sonorant]). However, neither the closure nor the release of a voiceless stop are associated with [+sonorant], whereas the closure of a prenasalized stop is associated with this feature specification. Therefore, the mapping from one to the other violates Ident([+sonorant]). The reader can easily verify that mappings between homorganic voiceless stops, prenasalized stops and nasal consonants incur the following violations, where a check mark indicates constraint satisfaction and a cross indicates constraint violation:

(79) Faithfulness violations of oral/nasal mappings of consonants:

Mapping	Constraint violations		
	Ident([voice])	Ident([-sonorant])	Ident([+sonorant])
t ↔ n	✖	✖	✖
t ↔ ⁿd	✖	✔	✖
ʤ ↔ ɲ	✔	✖	✖
ⁿd ↔ n	✔	✖	✔

5. THE SPLIT ANALYSIS OF NASAL HARMONY IN MBYA

In this section, I analyze nasal harmony in Mbya as the result of two distinct processes: nasal harmony between adjacent syllable nuclei, and nasal coarticulation between pairs of adjacent vowels and consonants. Transparency is attested when nucleus to nucleus nasal harmony takes place without nasal coarticulation of the intervening consonant.

5.1. Nuclei nasal harmony

Nasal harmony between adjacent syllable nuclei is enforced by an agreement constraint agree-σ([nasal]):

(80) agree-σ([±nasal]): Let σ_1 and σ_2 be two adjacent syllables in the output. The nucleus of σ_1 is linked to [αnasal] if and only if the nucleus of σ_2 is linked to [αnasal].

agree-σ([±nasal]) conflicts with a faithfulness constraint Ident-V([±nasal]):

(81) Ident-V([±nasal]): Let x be a vowel in the input and y its correspondent in the output; x is linked to [αnasal] if and only if y is linked to [αnasal].

Ranking agree-σ([nasal]) above Ident-V([nasal]) forces morphemes to be either completely nasal or completely oral. Note that this effect is not directional, as illustrated by the following examples, using the hypothetical inputs /atãta/ and /ãtatã/, in a hypothetical language with bi-directional harmony:

(82) /atãta/ → [atata]

	atãta	agree-σ([±nasal])	Ident-V([±nasal])
☞	atata		*
	ãtãtã		*!*
	atãta	!**	

(83) /ãtatã/ → [ãtãtã]

	ãtatã	AGREE-σ([±nasal])	IDENT-V([±nasal])
☞	ãtãtã		*
	atata		*!*
	ãtatã	!**	

Two candidates may be tied when they have an equal number of nasal and oral vowels in their input; this is illustrated with the hypothetical input /ãta/:

(84) /ãta/ → { [ata], [ãtã] }

	/ãta/	AGREE-σ([±nasal])	IDENT-V([±nasal])
☞	ãtã		*
☞	ata		*
	ãta	!*	

In a language with bi-directional nasal harmony, this tie may be broken by a high ranking Max([+nasal]) constraint, forcing the complete nasalization of outputs whose inputs have at least one nasal nucleus:

(85) Max([+nasal]): Each occurence of the feature specification [+nasal] in the input must be preserved in the output.

In Mbya, we will see that higher positional faithfulness to an underlying [nasal] feature on stressed vowels plays the role of the tie breaker, as we have come to expect since early analyses of nasal harmony in Guarani (Gregores and Suárez, 1967; Lunt, 1973; Rivas, 1975). Indeed, regressive nasalization in Mbya is attested with two types of triggers: a stressed nasal vowel, or a root-internal prenasalized stop. Let us put aside prenasalized stops for the moment and focus on regressive nasal harmony triggered by stressed nasal vowels. But first, a few words on stress placement are required.

I will assume Beckman's (1998) analysis of stress in Guarani roots. An undominated Ft-Form:Trochee constraint requires that every foot be trochaic (I will assume that trochees are syllabic in Mbya). An undominated Align-Ft-Rt constraint requires that every foot appear at the right edge of a morpheme, which accounts for obligatory final or penultimate stress. The ranking Align-Ft-Rt » Ft-Bin allows degenerate single syllable trochees, which accounts for root-final stress. A constraint Head-Max requires that segments that are prosodic heads in the input are prosodic heads in the output. Head-Max dominates Ft-Bin, which allows a degenerate foot in the input to be preserved in the output. However, Ft-Bin is dominated by Align-Ft-Rt, which prevents a prosodic foot that is not right aligned in the input to surface as such in the output. The alternation between penultimate and final stress is lexical, and is not captured by the ranking. Since the focus of this paper is not on stress, I will omit these constraints from the OT tableaux discussed in the examples, and I will only consider outputs that satisfy Beckman's analysis.

Coming back to nasal harmony, I assume that faithfulness to nasality on stressed vowels dominates faithfulness to nasality on vowels (irrespective of stress), i.e. IDENT-"V([nasal]) » IDENT-V([nasal]).

(86) IDENT-ˈV([±nasal]): Let x be a stressed vowel in the input and y its correspondent in the output; x is linked to [αnasal] if and only if y is linked to [αnasal].

(87) IDENT-V([±nasal]): Let x be a vowel in the input and y its correspondent in the output; x is linked to [αnasal] if and only if y is linked to [αnasal].

(88) /akˈã/ → [ãkˈã]

aˈkã	AGREE-σ([±nasal])	IDENT-ˈV([±nasal])	IDENT-V([±nasal])
☞ ãˈkã			*
aˈka		!*	
aˈkã	!*		

When stress falls on an oral vowel in the input, the ranking will force the deletion of [+nasal] on an unstressed vowel:

(89) /tʃĩˈpa/ → [tʃiˈpa]

tʃĩˈpa	AGREE-σ([±nasal])	IDENT-ˈV([±nasal])	IDENT-V([±nasal])
☞ tʃiˈpa			*
tʃĩˈpã		!*	
tʃĩˈpa	!*		

Therefore, higher positional faithfulness of nasality to stressed vowel accounts for the leftward directionality of nasalization in Mbya. A prediction of this analysis is that, in a root with a penultimate stressed nasal vowel, the unstressed final vowel cannot be oral. Unfortunately, I have been unable to find a root that would allow me to test this prediction.

5.2. Nasal coarticulation: vowel to consonants

Consonants are affected by nasal harmony through a system of nasal coarticulation with adjacent vowels. I propose to distinguish two forms of coarticulation. One is nasalization of a vowel due to an adjacent nasal consonant (edge), the other is nasalization of a consonant (edge) due to an adjacent nasal vowel. Let us begin with the second type of coarticulation. I propose that it results from the interactions of two sets of constraints, which are relativized to consonant categories. One set of markedness constraints *CṼpenalizes nasal vowels adjacent to oral consonant edges in the output. One set of faithfulness constraints IDENTIO-C([-nasal]) penalizes mappings from oral consonants in the input to nasal consonants in the output:

(90) *CṼ: Assign one violation for each [+nasal] vowel adjacent to one of the edges of a consonant of category C, which is linked to [-nasal].

(91) IDENTIO-C([-nasal]): Let x be a consonant of category C in the input, and y its correspondent in the output. If x is linked to [-nasal], then y is linked to [-nasal].

These sets of constraints are universally ordered as in (92) and (93), where T stands for oral voiceless stop, D for oral voiced stops, S for oral voiceless fricatives, Z for oral voiced fricatives, L for oral liquids and J for oral glides:

(92) *JṼ » *LṼ » *ZṼ » *SṼ » *DṼ » *TṼ

(93) IdentIO-T([-nasal]) » IdentIO-D([-nasal]) » IdentIO-S([-nasal]) » IdentIO-Z([-nasal]) » IdentIO-L([-nasal]) » IdentOI-J([nasal])

These two scales are based on the sonority hierarchy (Jespersen, 1904; Gnanadesikan, 1997). The first scale states that disharmonic *CṼ sequences are more marked the more sonorant C is. The second states that the less sonorant a consonant C is, the more faithful to orality it is. Taken together, these two scales capture the idea that sonorancy facilitates nasalization. In Mbya, these constraints are ordered as follows:

(94) IdentIO-T([-nasal]) » *JṼ » *LṼ » *ZṼ » *SṼ » *DṼ » *TṼ » IdentIO-D([nasal])

Given this ranking, all consonants except voiceless stops (and voiceless affricates, which are lumped with stops in (92)) are predicted to undergo nasal harmony. The following example illustrates this mechanism:

(95) /iˈrũ/ → [ĩˈr̃ũ]

	/iˈrũ/	AG-σ([±nas])	Id-ˈV([±nas])	*LṼ	Id-V([±nas])	IdIO-L([-nas])
☞	ĩˈr̃ũ				*	*
	ĩˈrũ			!*	*	
	iˈru		!*			
	iˈrũ	!*				

A consonant is transparent to nasal harmony when it belongs to a category C such that both IdentIO-C([-nasal]) and AGREE-σ([nasal]) dominate *CṼ. This is the case with voiceless stops, as illustrated in the following example. The optimal candidate incurs two violations of *TV˜, since the two edges (aperture positions) of the stop [k] in the output are adjacent to a nasal vowel. Mapping the input to [ãˈŋã] is ruled out because of a violation of IdentIO-T([-nasal]). As for mapping the input to [ãˈᵑgã], this is ruled out by the universal ranking or *D˜V above *TV˜.

(96) /aˈkã/ → [ãˈkã]

	/aˈkã/	AG-σ ([±nas])	IdIO-T([-nas])	Id-ˈV ([±nas])	*DṼ	Id-V ([±nas])	*TṼ
☞	ãˈkã					*	**
	ãˈᵑgã				!*	*	
	aˈka			!*			
	ãˈŋã		!*		*	*	
	aˈkã	!*					*

Blocking of nasal harmony by voiceless stops occur in any given language if and only if IdentIO-T([-nasal]) dominates *TṼ and agree-σ([nasal]) does not dominate *TṼ. In that case, mapping the input /a'pã/ to the candidate [ã'mã] is ruled out due to a violation of the undominated IdentIO-T([-nasal]) constraint. Furthermore, if *TṼ does not dominate agree-σ([nasal]), then the candidate [a'pã] is favored over [ã'pã], since both candidates are tied as far as their violations of *TṼ and agree-σ([nasal]) are concerned, but the latter incurs a violation of Ident-V([nasal]). If *TṼ dominates agree-σ([nasal]), then [a'pã] is favored over [ã'pã] since the former incurs less violations of *TṼ than the latter. This is illustrated by the following hypothetical examples:

(97) /aˈpã/ → [aˈpã] (hypothetical example, unattested in Mbya)

/aˈpã/	IdIO-T([-nas])	Id-ˈV([±nas])	*TṼ	AGσ([±nas])	Id-V([±nas])
☞ aˈpã			*	*	
ãˈpã			**		!*
aˈpa		*!			*
ãˈmã	!*				*

(98) /aˈpã/ → [aˈpã] (hypothetical example, unattested in Mbya)

/aˈpã/	IdIO-T([-nas])	Id-ˈV([±nas])	*TṼ	AGσ([±nas])	Id-V([±nas])
☞ aˈpã			*	*	
ãˈpã			*!*		*
aˈpa		*!			*
ãˈmã	!*				*

5.3. Nasal coarticulation: consonant to vowel

In subsection 5.2, I proposed an analysis of nasalization of consonants by adjacent nasal vowels. Let us now look at the opposite phenomenon: nasalization of vowels by adjacent consonant edges. In section 3.1.2 , it was observed that nasal consonants are always preceded and followed by nasal vowels, and prenasalized stops are always preceded by nasal vowels:

(99) *ˈma

(100) *aˈ^{m}ba

The representation of prenasalized stops that was proposed in section 4 will be helpful to explain these generalizations. I propose that nasalization of vowels by adjacent nasal consonant (edges) is due to a high ranked markedness constraint *NV, which is violated by every oral vowel adjacent to a nasal consonant edge[2]:

(101) *NV: Assign one violation for each consonant edge linked to [+nasal] and adjacent to a vowel that is linked to [-nasal].

---

[2] Note that this constraint is not directional, so that there is no need to invoke a separate *VN constraint.

When a nasal vowel occurs in a root with an oral stressed vowel, *NV conflicts with AGREE-σ([nasal]) and IDENT-'V([nasal]). Consider for instance the input /'ma/. Its faithful output ['ma] violates *NV. Yet, sequences of nasal consonants and oral vowels are unattested in Mbya. As a consequence, either the stressed vowel should be nasalized in the output, or the nasal consonant should be partially or completely denasalized, as illustrated in the following examples:

(102) a. /ˈma/ → [ˈmã]
b. /ˈma/ → [ˈpa]
c. /ˈma/ → [ˈᵐba]

The first of these mappings would be attested if we ranked *NV over IDENT-'V([nasal]). However, this ranking would fail to account for the fact that the nasal forms of suffixes that alternate between an oral onset and a nasal onset never occur after roots whose stressed vowel is nasal, i.e. outputs such as *[teko'a+mɨ̃] are unattested:

(103)	a.	tekoˈa+pɨ	‘in the village’
	b.	tẽˈtã+mɨ̃	‘in the city’
	c.	*tekoˈa+mɨ̃	

In order to rule out mappings like /teko'a+mɨ̃/ → *[teko'a+mɨ̃], IDENT-"V([nasal]) must be ranked at least as high as *NV.

This leaves us with the last two mappings in (102). To see which of these mappings is optimal, consider again the faithfulness violations of mappings from voiceless stops to nasal or prenasalized consonants:

(104) Faithfulness violations of oral/nasal mappings of consonants:

Mapping	Constraints violation		
	IDENT([voice])	IDENT([-sonorant])	IDENT([+sonorant])
t ↔ n	✖	✖	✖
t ↔ ⁿd	✖	✔	✖
ʤ ↔ ɲ	✔	✖	✖
ⁿd ↔ n	✔	✖	✔

Since the mapping from voiceless stops to nasal consonants incurs more faithfulness violations than the mapping from voiceless stop to prenasalized consonants, we predict that the mapping from /'ma/ to ['ᵐba] is optimal:

(105) /ˈma/ → [ˈᵐba]

	ˈma	*NV	IDENT-ˈV([nas])	IDENT([voice])	IDENT([-son])
☞	ˈᵐba				*
	ˈpa			!*	*
	ˈmã		!*		
	ˈma	!*			

5.4. Prenasalized stops

We are now in a position to explain the restricted distribution of prenasalized stops. The fact that prenasalized stops are never followed by nasal vowels is explained by ranking *TṼ above IDENT([-sonorant]):

(106) /ᵐbã/ → [mã]

	ˈᵐbã	ID-ˈV([±nas])	*DṼ	*TṼ	ID-([-son])	ID-([voice])
☞	ˈmã				*	
	ˈpã			!*		*
	ˈᵐbã		!*			
	ˈᵐba	!*				

The fact that *DṼ is ranked over *TṼ explains why voiceless stops may not be mapped to prenasalized stops inside a nasal span, in order to minimize violations of *TṼ:

(107) /ãˈpã/ → [ãˈpã]

	ãˈpã	*DṼ	*CṼ	ID-([-son])	ID-([voice])
☞	ãˈpã		**		
	ãˈᵐbã	!*		*	*

The fact that prenasalized stops are never preceded by an oral vowel in a root and its prefixes is explained by ranking *NV above Ident-V([nasal]):

(108) /aˈᵐba/ → [ãˈᵐba]

	aˈᵐba	*NV	IDENT-V([±nasal])
☞	ãˈᵐba		*
	aˈᵐba	!*	

It is less straightforward to explain the fact that prenasalized stops may occur as a buffer in disharmonic roots. Indeed, the current set of constraints and their rankings predict that the input /ã'ᵐba/ should surface as [a'pa] rather than [ã'ᵐba], since AGREE-σ([nasal]) dominates faithfulness to sonority and voice and faithfulness to nasality on unstressed vowels:

(109) ?/ãˈᵐba/ → [aˈpa]

	ãˈᵐba	AG-σ ([±nas])	ID([voice])	ID([-son])	ID-V([±nas])
	aˈpa		*	*	*
☹	ãˈᵐba	!*			

I propose that disharmonic roots arise due to a pressure to preserve the nasality of consonants in the input, which is captured by a high ranking IDENTIO-C([+nasal]):

(110) IdentIO-C([+nasal]): Let *x* be a consonant of category C in the input, and *y* its correspondent in the output. If *y* is linked to [+nasal], then *x* is linked to [+nasal].

Ranking IdentIO-C([+nasal]) over Agree-σ([nasal]), along with *NV and Ident-'V([nasal]), accounts for the widely shared intuition (see Gregores and Suárez, 1967; Lunt, 1973; Rivas, 1975) that there are two triggers of nasalization in Mbya: stressed nasal vowels, and nasal consonants.

The workings of this ranking are illustrated in the next two examples:

(111) /ãˈᵐba/ → [ãˈᵐba]

	ãˈᵐba	IdIO-C ([+nas])	AG-σ ([±nas])	Id([voice])	Id([+son])	Id-V([±nas])
☞	ãˈᵐba		*			
	aˈpa	!*		*	*	*

(112) /ãˈma/ → [ãˈᵐba]

	aˈma	*NV	Id-ˈV([±nas])	IdIO-C ([+nas])	AG-σ([±nas])	Id-([-son])
☞	ãˈᵐba				*	*
	aˈpa			!*		
	ãˈmã		!*			
	ãˈma	!*				

Finally, note that in roots with prenasalized stops, the combined effect of the constraints *NV and AGREE-σ([nasal]) may trigger leftward nucleus to nucleus nasalization even when the stressed vowel is oral. This is illustrated with the root [tãtã˜e'ⁿdɨ] (*lantern*):

(113) /tataeˈⁿdɨ/ → [tãtãẽˈⁿdɨ]

	tataeˈⁿdɨ	*NV	Id-ˈV([±nas])	AG-σ([±nas])	IdIO-D ([-nas])	Id-V([±nas])
☞	tãtãẽˈⁿdɨ			*		***
	tataẽˈⁿdɨ			!**		*
	tãtãẽˈnɨ̃		!*		*	***
	tataeˈⁿdɨ	!*				

Let us close this subsection with a summary of the ranking that we have arrived at:

(114) *NV, Ident-ˈV([±nasal]) , IdentIO-C([+nasal])
»
AGREE-σ([±nasal]), IdentIO-T([-nasal])
»
*DṼ
»
*TṼ, Ident-V([±nasal]), Ident([voice]), Ident([±sonorant]), IdentIO-D([-nasal])

5.5. Sandhi prenasalization

Recall that sandhi prenasalization occurs when a voiceless stop at the onset of a root or suffix follows a root final nasal vowel, the two morphemes being in the same prosodic domain:

(115)	ãˈkã	‘head’
	ˈka	‘hit’
	ãˌkã#ˈᵑga	‘head hitting’

This phenomenon can be analyzed as an minimization of *TṼ violations at the expense of faithfulness to [voice] and [sonorant], which are demoted one rank down:

(116) /ãˌkã#ˈka/ → [ãˌkã#ˈᵑga]

	ãˌkã#ˈka	ID-ˈV ([±nas])	IDIO-T([-nas])	AG-σ ([±nas])	*TṼ	ID-V ([±nas])	ID ([voice])	ID ([±son])
☞	ãˌkã#ˈᵑga			*	**			*
	ãˌkã#ˈka			*	*!**			
	aˌka#ˈka	!*				*		
	ãˌkã#ˈŋã	!*	*		**		*	*

Because of the transparency of voiceless stops to nasal harmony, alternations between completely oral onsets and completely nasal onsets in suffixes, as illustrated in (117), cannot be predicted in the grammar. Therefore, alternations such as /pɨ/ ~ /mɨ̃/ must be analyzed as cases of lexical allomorphy.

(117)	tekoˈa+pɨ	‘In the village.’
	tẽˈtã+mɨ̃	‘In the city’

Note that when a root is inserted in the first position in a compound, or when it is followed by a stressed suffix, its stress is demoted to secondary stress. This is illustrated in (115). I will nevertheless assume that vowels that bear secondary stress are subject to the constraint Ident-'V([nasal]). This being said, it is unclear whether self-standing roots with three syllables or more have secondary stress, and how this affects nasalization. A more detailed analysis of the interaction between secondary stress and nasal harmony will have to be left for further research.

The final ranking is as follows

(118) *NV, IDENT-ˈV([±nasal]) , IDENTIO-C([+nasal])
»
AGREE-σ([±nasal]), IDENTIO-T([-nasal])
»
*DṼ
»
*TṼ, IDENT-V([±nasal]), IDENTIO-D([-nasal])
»
IDENT([voice]), IDENT([±sonorant])

6. TYPOLOGICAL CONSIDERATIONS

Piggott (1992) observed that cross-linguistic variations in the relative distribution of segments that undergo nasal harmony and segments that block nasal harmony is subject to limits that are summarized in the following table:

(119) Hierarchical variation in nasal harmony:

Vowels	**Glides**	**Liquids**	**Fricatives**	**Obs. Stops**	Spanish
Vowels	**Glides**	**Liquids**	**Fricatives**	**Obs. Stops**	Sundanese
Vowels	*Glides*	**Liquids**	**Fricatives**	**Obs. Stops**	Malay
Vowels	*Glides*	*Liquids*	**Fricatives**	**Obs. Stops**	Ijo
Vowels	*Glides*	*Liquids*	*Fricatives*	**Obs. Stops**	Gaelic

Piggott's (1992) generalizations are captured by the proposed analysis, due to the inverse orderings of the scales in (92) and (93), repeated here in (120) and (121):

(120) *JṼ » *LṼ » *ZṼ » SṼ » *DṼ » *TṼ

(121) IdentIO-T([-nasal]) » IdentIO-D([-nasal]) » IdentIO-S([-nasal]) » IdentIO-Z([-nasal]) » IdentIO-L([-nasal]) » IdentOI-J([nasal])

As was observed in section 5.2, everything else being equal, a segment *x* of category C blocks nasal harmony if and only if IdentIO-C([-nasal]) dominates both *CṼ and agree-σ([nasal]). Therefore, if a segment *x'* of a category C' (e.g. liquids) blocks nasal harmony, then any segment x' of a category C' such that *C'Ṽ is less marked than *CṼ (e.g. voiced fricatives) will also block nasal harmony, since in that case *CṼ dominates *C'Ṽ, IdentIO-C'([-nasal]) dominates IdentIO-C([-nasal]), which dominates both *CṼ and agree-σ([nasal]), and therefore by transitivity IdentIO-C'([-nasal]) dominates *C'Ṽ and agree-σ([nasal]).

Moreover, everything else being equal, a segment *x* of category C undergoes nasal harmony if and only if *CṼ dominates IdentIO-C([-nasal])[3]. Therefore, if a segment *x* of category C (e.g. voiced fricatives) is a target for nasal harmony, then any segment x' of a category C' such that *C'Ṽ is more marked than *CṼ (e.g. liquids) will also be a target for nasal harmony, since *C'Ṽ dominates *CṼ, which dominates IdentIO-C([-nasal]), which dominantes IdentIO-C'([-nasal]).Therefore, *C'Ṽ dominates IdentIO-C'([-nasal]) by transitivity.

In sum, Piggott's typological observations are accounted for in the proposed analysis, by adopting the scales in (120)-(121).

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[3] This guarantees nasalization of consonants of category C by adjacent nasal vowels. In order to guarantee vowel to vowel nasalization, one must also assume that Agree-σ([nasal]) dominates Ident-V([nasal]).

7. DISCUSSION

7.1. Two kinds of nasal harmony

According to the proposed analysis, nasal harmony results from the interaction of vowel-to-vowel harmony with consonant-to-vowel coarticulation. This assumption predicts the existence of languages in which vowels agree in nasality with adjacent edges of consonants, without any vowel-to-vowel nasal harmony taking place. In such a language, AGREE-σ([nasal]) would be ranked below IDENT-V([nasal]), preventing vowel-to-vowel harmony to take place, while *CṼ and possibly *NV would be ranked over IDENT-C([-nasal]) and IDENT-V([nasal]). The question then arises whether such languages are attested. Kaingang (Macro-Gê) seems to instantiate this form of nasal harmony limited to C-to-V effects. The data in this section are from D'Angelis (1998). Disharmonic roots are attested in Kaingang. The boundary between a nasal and an oral syllable can be marked by a nasalized sonorant, showing that such disharmony cannot be analysed as blocking:

(122)	kɨˈɾ̃ũ	*boy*

However, C-to-V nasal harmony is clearly attested. Firstly, oral vowels are never attested adjacent to nasal consonants. A nasal consonant is always adjacent to a nasal vowel. Pre- and post-nasalization is also attested, the oralized edge of a nasal consonant being always adjacent to an oral vowel:

(123)	ˈmɔ̃	*Jabuticaba*
	ˈmbɔ	*sprig*
	tiˈdndugŋ	*his belly*

Moreover, sonorant consonants obligatorily agree in nasality with an adjacent tautosyllabic vowel:

(124)	ˈɾoɾ	*round, low*
	ˈɾ̃ɔ̃	*sun*
	ˈjɔgŋ	*father*
	j̃ũ	*brave*

Therefore, splitting nasal harmony into separate processes of V-to-V and C-to-V harmony finds typological support in the analysis of Kaingang.

7.2. Comparison with Piggott and van der Hulst (1997)

Piggott and van der Hulst (1997) distinguish two kinds of nasal harmony systems: type A systems, with no transparent segments, and type B systems, which include transparent segments. In order to avoid an opaque analysis of transparency while retaining locality constraints on harmony systems as much as possible, Piggott and van der Hulst (1997) argue that type A systems and type B systems differ in their mechanism of spreading. Type A systems are analyzed standardly as cases of segment-to-segment nasal spreading, which without opacity predicts the absence of transparent segments. Type B systems, however, are analyzed as nasal harmony at the level of the syllable. The [nasal] feature in these systems is assumed to propagate from a nasal syllable to an adjacent syllable. In addition, Piggott and van der Hulst (1997) argue that whereas the feature [nasal] is defined as a segmental feature in type A systems, it is a suprasegmental syllabic feature in type B systems. This assumption is made more precise in the framework of Dependency Phonology. In type B systems, [nasal] is a property of syllable heads, and has to maintain a head position in all its manifestations. Piggott and van der Hulst (1997) then argue that sonorants that are tautosyllabic with a syllable head participate in its head position, whereas tautosyllabic obstruents are in a dependent position inside the syllable. Hence, this system predicts that in type B systems, nasality will spread from nucleus to nucleus, affecting sonorant onsets and codas, but skipping obstruents.

This system predicts transparency of obstruents in nasal harmony, using an analysis similar to the one I presented in this paper: nasal harmony is the result of the interaction of two different processes, one being nucleus-to-nucleus nasal harmony, and the other a form of C-to-V harmony. However, one can raise two objections to Piggott and van der Hulst's analysis. First, it fails to account for nasal harmony as a unified phenomenon, since the [nasal] feature occupies different positions in the feature geometry of type A and type B languages. By contrast, the analysis presented in this paper accounts for the two types of nasalization only by reordering a single set of constraints, as discussed in the previous section. Secondly, Piggott and van der Hulst (1997) restrict C-to-V nasal harmony processes in type B languages to the syllabic domain. This might be legitimate in the sample of languages that Piggott and van der Hulst (1997) have analyzed, but we have seen that in Mbya consonants may be nasalized by an adjacent vowel that belongs to a different syllable and even to a different morpheme, as is the case in Sandhi nasalization (see examples (64)-(66)). The analysis that I proposed seems to be free of these problems.

7.3. Comparison with Walker (1998)

Walker (1998) analyses nasal harmony as the interaction of a constraint of nasal spreading, with a series of markedness constraints militating against the presence of nasal segments in the output. According to Walker, a feature associated with a segment might spread locally to adjacent segments, when a single occurrence of the feature is linked to several segments. This autosegmental conception of spreading allows Walker to formulate a locality constraint on feature spreading, by outlawing gapped representations. A feature F cannot be linked to two segments s_1 and s_3 if a segment s_2 intervening between them is not linked to F.

An important aspect of Walker's analysis is that it uses a scale of markedness constraints in order to capture Piggott's (1992) observations on the distribution of targets and blockers:

(125) *NASALOBSTRUENTSTOP » *NASALFRICATIVE » *NASALLIQUID » *NASALGLIDE »
*NASALVOWEL

Note that there is a category of languages which is unattested in Piggott's (1992) hierarchy, namely languages in which all classes of segments are targets of nasal harmony, including obstruent stops. Walker argues that this category of languages exists and consists of languages in which obstruent stops are transparent, transparency being analyzed as opaque targets of nasal spreading. According to Walker, the opacity analysis of transparency simplifies the typology of nasal harmony, by integrating languages with transparent stops to Piggott's (1992) hierarchy in the following way:

Vowels	**Glides**	**Liquids**	**Fricatives**	**Obs. Stops**	Spanish
Vowels	**Glides**	**Liquids**	**Fricatives**	**Obs. Stops**	Sundanese
Vowels	*Glides*	**Liquids**	**Fricatives**	**Obs. Stops**	Malay
Vowels	*Glides*	*Liquids*	**Fricatives**	**Obs. Stops**	Ijo
Vowels	*Glides*	*Liquids*	*Fricatives*	**Obs. Stops**	Gaelic
Vowels	*Glides*	*Liquids*	*Fricatives*	*Obs. Stops*	Tuyuca, Guarani, Mbya

Walker derives these restrictions on the respective distribution of blockers and targets thanks to her universal scale of markedness for nasalized segments. A segment in a category C blocks nasal harmony iff *Nasal(C) » Spread(+nasal). Hence, if C blocks, all categories of segments X such that *Nasal(X) » *Nasal(C) will block as well. Conversely, since a segment in a category C is a target of nasal harmony iff *Nasal(C) « Spread(+nasal), all categories of segments X such that *Nasal(X) « *Nasal(C) will be targets.

At this point, an important question remains to be addressed. If transparent segments are actually opaque undergoers, why do they not surface as nasal segments? Put another way, why are obstruent stops the only segments that can be transparent, and that never surface as true undergoers of nasality? Walker argues that this is so because obstruent stops cannot be phonetically realized as obstruents, i.e. segments with a burst, and bear the feature [+nasal].

A first issue with Walker's analysis is opacity itself. The analysis of opaque phenomena requires powerful machinery, and everything else being equal, it is preferable to analyze as many phenomena as possible as non opaque.

Walker's main argument for an opacity analysis of transparent segments is that only obstruent stops are transparent, and they are always so. All other segments must be either targets or blockers. This uniqueness of obstruent stops calls for an explanation, which Walker finds in the fact that obstruent stops cannot both have a burst and be audibly nasal. There are two issues with this argument. The first is that Walker does not explain why obstruent stops would have to retain a burst and be [-sonorant] when they undergo nasalization. There are certainly languages in which voiced obstruent stops surface as nasal consonants inside a nasal span. This is the case in Mbya, as we have seen, but also in Tuyuca (cf. Walker, 1999b). Voiced obstruent stops are [-sonorant] and have a burst. When they undergo nasal harmony, they surface as nasal sonorant consonants, without a burst. This is unexpected in Walker's analysis. A second issue is that obstruent stops are arguably not the only segments that can be transparent to nasal harmony. Piggott and van der Hulst (1997) claim that fricatives are transparent in Barasano. Yet, fricatives are not phonetically incompatible with nasality.

In sum, it appears that transparent segments cannot be reduced to opaque targets. Hence, the analysis of transparency that I proposed in this paper, according to which transparent segments are truly oral, is preferable to Walker's analysis.

7.4. Prenasalized stops and iterative nasalization

Steriade (1993) observes that prenasalized stops are generally unattested in the output of iterative nasalization. In Steriade's analysis, iterative processes of nasalization are expected to affect both the closure and the release of oral stops, which excludes the generation of prenasalized stops. From this perspective, the existence of prenasalized stops in Guarani comes as a surprise, since regressive nasal harmony is iterative and affects every segments between a nasal trigger (stressed nasal vowel or nasal consonant) and the left boundary of the stem, putting aside transparent voiceless stops and voiceless affricates.

Note that the fact that prenasalized stops are never attested in the nasal span of a stressed nasal vowel does not challenge the relevance of Steriade's observation. Indeed, we have seen that voiceless stops may surface as prenasalized stops at the boundary between a nasal root and an oral root or suffix. Therefore, the question remains: why is it the case that voiceless stops may surface as prenasalized segments in sandhi prenasalization, while they are transparent to leftward nasal harmony? It is not clear that an analysis that posits a single mechanism of iterative nasal spreading to account for nasal harmony in Guarani can explain this set of facts, hence Steriade's observation.

The proposed analysis deals with this phenomenon by teasing apart vowel to vowel nasal harmony and consonant/vowel nasal coarticulation. Prenasalized stops are unattested inside a nasal span due to a violation of the *DṼ markedness constraint. In sandhi prenasalization and in disharmonic roots, the [-nasal] voiced edge of prenasalized stops is not adjacent to a nasal vowel, and therefore *DṼ is satisfied.

Note that the use of a binary nasal feature is crucial in this analysis. Indeed, it is important that the constraint IdentIO-T([-nasal]) is violated in the mapping from voiceless stops to nasal consonants but not in the mapping from voiceless stops to prenasalized stops: while each of these mappings introduce a [+nasal] feature in the output that is absent in the input, only the second of these mappings preserves a [-nasal] feature in the output that is present in the input. This difference accounts for the fact that although voiceless stops are transparent (IdentIO-T([- nasal]) and Agree-σ([nasal]) dominate *TṼ), they may still surface as prenasalized stops (no violation of IdentIO-T([-nasal])) due to nasal coarticulation (*TṼ dominantes Ident([voice]) and Ident([sonorant])), provided their [-nasal] edge is not adjacent to a nasal vowel (*DṼ dominates *TṼ).

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