Ikwere Nasal Harmony in Typological Perspective

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1. Introduction

A number of languages, including several spoken in West Africa, have systems of nasal harmony in which a morpheme-level feature of nasality spreads over certain domains, most commonly the word. In most such systems, the spread of nasality is arrested by certain types of consonants, always including voiceless obstruents and frequently other sounds as well. The class of sounds that arrests nasal harmony is not arbitrary, but typically consists of a continuous portion of the scale in (1), starting from the top:

(1) Nasal resistance scale

voiceless stops	MOST RESISTANT TO NASALIZATION
voiceless fricatives/voiced stops	
voiced fricatives	
implosives (and other nonexplosive stops)	
liquids	
glides	
vowels	MOST SUBJECT TO NASALIZATION

For example, in some languages only voiceless obstruents arrest the spread of nasalization, in others all obstruents except voiced fricatives resist nasalization, while in yet others all obstruents do so, and so forth. But there are no known languages in which, for example, just voiced stops and liquids, or voiced fricatives but not voiceless stops, resist nasalization. (See Walker 1998 for a review of data from many genetically unrelated languages.) Exceptions to this pattern often prove to result from historical developments which have made the phonetic basis of nasalization synchronically arbitrary (Hyman 1982).

This paper addresses the question: why are some consonants more resistant to nasalization than others? It presents data from Ikwere, an Igboid language spoken in Nigeria, which sheds new light on this question. As we shall see, Ikwere has a pattern of nasal harmony which spreads nasality across certain domains within the word. Certain consonants undergo nasalization while others block its spread. The class of blocking segments comprises all obstruent stops and fricatives. However, two labial stops, *ḅ* and *’ḅ*, represent an apparent exception in that they fail to block nasalization. A phonetic study of these sounds, reported below, shows that they are not in fact obstruents, but nonexplosive stops, produced with no buildup of air pressure behind the labial closure. The full generalization is thus that all and only obstruents block nasalization. On the basis of this result, it will be proposed that the property underlying the nasal resistance scale in (1) is *obstruence*.

The discussion proceeds as follows. Section 2 presents an overview of nasal systems and nasal harmony from a crosslinguistic perspective. Section 3 then examines nasal harmony in Ikwere, showing that nasality functions as a morpheme-level feature that spreads to continuous strings of nonobstruent segments in its domain. Section 4 shows that the phonological and phonetic property that characterizes the class of nonnasalizable segments in Ikwere is that of *obstruence*, defined as the buildup of air pressure behind the oral closure. Section 5 discusses evidence that [±obstruent] is a different feature from [±sonorant], referring to a partly different dichotomy and having a different phonetic definition. Finally, section 6 places Ikwere nasal harmony in a typological perspective, and proposes to interpret resistance to nasalization in terms of an obstruence scale, reflecting the degree to which a given sound obstructs the passage of the airstream.

2. An Overview of Nasal Harmony

Cohn (1993) recognizes four types of nasal systems, depending on whether nasality is surface-distinctive in consonants, in vowels, in both, or in neither. These are given in the chart in (2). Figures in the column on the right show the number of languages representing each type in the 451-language UPSID-92 survey (Maddieson and Precoda 1989).

(2) Nasality is distinctive in:

	C	V	UPSID-92
Type 1	no	no	4
Type 2	no	yes	5
Type 3	yes	no	345
Type 4	yes	yes	97

Among these systems, types 1 and 2, in which nasality is nondistinctive in consonants, are statistically rare, but nevertheless well documented. Examples of Type 1 systems, in which nasality is not distinctive in any segment, include the Salishan languages and Quileute (North America), Pirahã and Mura (South America), and Rotokas (Papua New Guinea). Type 2 systems, in which nasality is surface-distinctive in vowels but not in consonants, are concentrated mostly in two zones: West Africa, where they are found in languages such as Ewe, Kpelle, and Bwamu, and South America, where they are found in languages such as Barasana, Tucano, and Warao. Type 3 systems, in which nasality is surface-distinctive only in consonants (e.g. English, Arabic), are the commonest, while Type 4 systems, in which nasality is surface-distinctive in both consonants and vowels (e.g. French, Portuguese), are somewhat less frequent.

Many languages with surface-distinctive nasality also have nasal harmony or assimilation. In some, nasality spreads only to other sounds in the same syllable, while in others nasality spreads across syllables, though usually within a well-defined larger domain such as the root, the stem, or the word. Such "long-distance" nasal spreading is widely reported in languages of Mexico, South America, Indonesia, and West Africa. It appears to be most often associated with Type 2 and 3 systems, in which nasality is distinctive in either consonants or vowels but not both.

Nasal harmony, as this term is most often used, is a type of nasal assimilation satisfying three criteria:

(3) a. nasality is distinctive at the level of the morpheme, not the segment;
b. nasal spreading is long-distance, that is, it crosses syllable boundaries;
c. alternating morphemes: certain morphemes are oral in oral contexts and nasal in nasal contexts.

By the first of these criteria, nasality commutes at the level of the morpheme. That is, morphemes either bear a single lexically-specified feature of nasality or they do not; if they do, this feature spreads predictably across the morpheme from its source segment (or in some cases a floating value). In a less common variant of this pattern, Barasana as described by Gomez-Imbert (1997) presents a three-way contrast among non-alternating nasal morphemes, non-alternating oral morphemes, and alternating morphemes whose orality or nasality is fully predictable from the context. The second criterion requires nasality to spread across syllable boundaries. The third requires the presence of at least some alternating morphemes. The convergence of all three criteria defines typical nasal harmony systems, though the term "nasal harmony" is also applied more loosely to systems lacking one or another of them.

Nasal harmony in the sense of (3) is well known in South American languages, but has been less often reported elsewhere. It appears to be most characteristic of Type 2 nasal systems, where nasality can often be regarded as a floating or suprasegmental feature in underlying representation. For recent theoretical treatments of nasal harmony based on cross-linguistic data, see Piggott 1992, Hume & Odden 1996, Walker 1998, and Peng 2000, among others.

3. Ikwere: a Type 2 Language with Nasal Harmony

Ikwere is a member of the Igboid family of languages spoken in Nigeria, which has been undocumented in the published literature until recently (see Osu 1998 for a general presentation). The data presented below have been collected as part of an ongoing project designed to bring Ikwere phonology to the attention of linguists. Our presentation draws in part on more detailed studies which appear elsewhere (Clements & Osu 2002; to appear). This section shows that Ikwere is a Type 2 language with nasal harmony in the sense of (3).

3.1. Ikwere as a Type 2 language

Ikwere has a system of eighteen surface-distinctive vowels. Nine are oral and nine are nasal, as shown in (4):

(4)	oral				nasal		
high:	i		u	[+ATR]	ḭ		ṵ
	ɪ		ʊ	[-ATR]	ɪ̰		ʊ̰
mid:	e		o	[+ATR]	ḛ		o̰
	ɛ		ɔ	[-ATR]	ɛ̰		ɔ̰
low:		a		[-ATR]		a̰	

Some of these vowels are less common than others (ɛ and ɛ̰ in particular are very infrequent). Ikwere also has a system of ATR (advanced tongue root) vowel harmony, according to which in most words, all non-low vowels are either [+ATR] or [-ATR]. This constraint accounts for regular alternations in grammatical morphemes; compare, for example, the first and third vowels in *ɔ̀ ḅá-lɛ́ꜜḿ (ɛ́f̣ɔ̃)* 's/he has run' and *ò rí-léꜜḿ (wírí)* 's/he has eaten', whose values for [±ATR] are determined by the vowels of the roots *ḅá* and *rí*. Examples given elsewhere in this paper illustrate ATR harmony in a wide variety of roots and words.

Examples of surface contrasts between oral and nasal vowels are shown in (5):

(5)	<u>oral</u>		<u>nasal</u>	
	ákà	'hand, arm'	ákà̰	'sickness of hens'
	è-h^{w}é	'to blow (of wind)'	è-ẖ^{w}ḛ́	'to float'
	ɛ̀sâ	'seven'	ɛ̀sá̰	'squirrel'
	ézí	'large'	ézḭ̀	'pig'
	ìdó	'peace'	ìdò̰	'shade of sun'
	ìg^{w}ù	'share' (n.)	íg^{w}ṵ́	'fishbone'
	ɔ̀dʊ̀	'a dry sauce'	ɔ́dʊ̰̀	'tail'

ɔ̀yɔ̀	'amicable gesture'	ɔ̀-ỹɔ̰́ (ńsḭ́)	'to defecate'

In addition to these vowels, a placeless, tone-bearing nasal vowel *ə̰*, probably representing a historical class prefix, occurs before consonants in some nouns. We conventionally transcribe this vowel as *m* before labial consonants and as *n* before other consonants, including *w*, as in words like *m̀fṵ̀* 'horn', *m̀pʊ́* 'jigger', *ńsḭ̀* 'odor', and *ńhʷù* 'loss'. All other nasal vowels are excluded in word-initial position.

Surface consonants occur in three phonologically-defined sets: obstruents, oral nonobstruents, and nasal nonobstruents, as shown in (6). (This classification will be justified on phonological and phonetic grounds in the following discussion.) All consonants occur both initially and intervocalically.

(6) Set A: obstruents

voiceless stops	p	t	c	k	kʷ		
voiced stops	b	d	j	g	gʷ		
voiceless fricatives	f	s					
voiced fricatives	v	z					

Set B: oral nonobstruents

plain voiced stop	ḅ						
glottalized stop	'ḅ						
lateral approximant		l					
central approximants		r	y	ɣ	w		
aspirates						h	hʷ

Set C: nasal nonobstruents

plain nasal stops	m	n					
glottalized nasal stop	'm						
central approximants		r̰	ỹ	ɣ̃	w̰		
aspirates						h̰	h̰ʷ

Of these sounds, *ḅ* and *'ḅ* are lax, labialized labial stops produced with no explosion at release. The latter is glottalized during the first part or all of its closure, and is typically imploded at release. Phonetic data showing how these sounds are distinguished from *p* and *b* will be provided below.

Consonants of Sets B and C are in complementary distribution before vowels: Set B consonants occur only before oral vowels and Set C consonants only before nasal vowels. Examples are shown in (7).

(7)

before oral vowels (Set B)		before nasal vowels (Set C)	
áḅá	'paint'	ámà̰	'matchet'
á'ḅá	'companionship'	à'mà̰	'path, road'
ɔ̀-lʊ́	'to marry'	ɔ̀-nʊ̰́	'to hear'
érú	'mushroom'	ɛ̰́r̰ʊ̰́	'work'
à-yá	'to return'	áỹâ̰	'eye'
à-ɣǎ	'to leave it'	à-ɣ̃á̰	'to bask in the sun'
è-wé (íꜜwê)	'to be spicy hot'	è-w̰ḛ́ (íꜜw̰ḛ́)	'to breathe'
à-hǎ	'to cut into pieces'	à-h̰á̰	'to suffice'
è-hʷé	'to blow (of wind)'	è-h̰ʷḛ́	'to float'

The distribution of set B and C consonants is thus fully predictable.[1] They can be grouped into phonemes as shown in (8):

(8)

phoneme	before oral vowels	before nasal vowels
/ ḅ /	ḅ	m
/’ḅ /	’ḅ	’m
/ l /	l	n
/ r /	r	r̰
/ y /	y	ỹ
/ ɣ /	ɣ	ɣ̃
/ w /	w	w̰
/ h /	h	ḛ
/ h^w /	h^w	$ḛ^w$

Direct evidence for three of these groupings comes from regular patterns of morpheme alternation, as shown in (9):

(9) l ~ n: ò rí-lém̀ ‘s/he has eaten’, ɔ̀ w̰ɔ̰́-nɛ̰́m̀ ‘s/he has drunk’
r ~ r̰: ɔ̀ byà-rʊ̀ nʊ̰̀ èkílé ‘s/he came yesterday’, ɔ̀ w̰ɔ̰̀-r̰ʊ̰̀ má̰ꜝỹá̰ ‘s/he drank some wine’
y ~ ỹ: ɔ́ bà̰-yá-lɛ́m̀ ~ ɔ́ bà̰-ỹá̰-nɛ̰́m̀ ‘s/he has come in’ (free variants)

The remaining pairings (*ḅ~m, ’ḅ~’m, ɣ~ɣ̃, w~w̰, h~ḛ, h^w~$ḛ^w$*) can be justified on the basis of feature similarity. Given this analysis, nasality can be regarded as fully predictable in consonants, as it is present if and only if the following vowel is nasal. (Henceforth, in order to simplify our transcriptions, nasality will not be indicated in the approximants *r̰ ỹ ɣ̃ w̰ ḛ $ḛ^w$*.)

Since nasality is contrastive in vowels but not in consonants, Ikwere is a Type 2 language according to the typology in (2).

3.2. Nasal harmony

It will now be shown that Ikwere has a system of nasal harmony satisfying the three criteria given in (3). The first two are exemplified in morpheme-level nasal harmony and the third in word-level nasal harmony. We discuss these levels in turn.

3.2.1. Nasal harmony at the morpheme level

It can easily be demonstrated that the feature of nasality in Ikwere is distinctive at the level of the morpheme, rather than the segment. As we shall show below, there are just two types of morphemes in Ikwere: those that are characterized by a feature of nasality and those that are not. If a morpheme is characterized by nasality, this feature may float, or be linked to at most one vowel. In all other respects its distribution across the morpheme is fully predictable.

In nasal morphemes, nasality spreads from its source across the maximal unbroken string of nonobstruent sounds within a domain which we call the "phonological root". This domain consists of a simple lexical or grammatical morpheme minus any initial V or rV syllable, if present. Thus, for example the domain of nasalization in *ɛ̀sá̰* ‘squirrel’ is *sá̰,* the domain of nasalization in *m̩̀fṵ̀* 'horn' is *fṵ̀*, and the domain of nasalization in *rɛ̀wʊ̰́* ‘deity’ is *wʊ̰́*. (The exclusion of initial V and rV syllable sequences from the nasalization domain is synchronically arbitrary, but is explained by the fact that these sequences often constituted prefixes in an earlier stage of the language. The phonological root as defined here also constitutes the domain of other morpheme-level patterns such as front/back vowel harmony.)

Examples of regular nasal harmony in monosyllabic domains are shown in (10a), in bisyllabic domains in (10b), and in trisyllabic domains in (10c).

(10) a) Nasal harmony in monosyllabic domains

ɛ̀sá̰	‘squirrel’	ɔ̀-wɔ̰́	‘to drink’
íkʷṵ́	‘age group’	ńyḛ́	‘person’
è-yḛ̌	‘to give’	rɛ̀wʊ̰́	‘deity’
m̀fṵ̀	‘horn’	rúhʷṵ́	‘face’

b) Nasal harmony in disyllabic domains

mɔ̰́nɔ̰̂	‘oil’	ɔ̀bà̰rà̰	‘blood’
wḛ́nḛ́	‘sibship’	ɔ́’má̰rá̰	‘first male child’
ríyò̰rò̰	‘charcoal’	mɔ̰́yɔ̰̂	‘urine’
ǹgʷḛ̀rḛ̀	‘lizard’	ɛ̀kà̰rà̰	‘strong odor’

c) Nasal harmony in trisyllabic domains (exhaustive list in our data):

ḿmḭ̀nḭ̀mḭ̀	‘species of tree’
ɔ́mḭ̀rḭ̀mà̰	‘meat, flesh’
ńwá̰rà̰-ká̰rá̰há̰	‘the year before last’
à-dǎ̰ íhʷɪ̰̀rɪ̰́ꜝhʷó̰	‘to be stupid’

Identifiable morpheme boundaries are indicated with dashes. It can be seen that in all cases, there is just a single unbroken nasal span. (It will be recalled that nasality is not indicated on approximants, in order to simplify our transcriptions; thus, for example, the *r* in the example 'charcoal' in (10b), although written without nasalization, is fully nasalized.) The nasal span in these examples contains only nonobstruents: vowels, liquids, and nasals. Nasal harmony does not spread to an initial obstruent or to an initial V or rV syllable, which lies outside the phonological root as defined above.

The examples in (10b) and (10c) show that nasalization crosses syllable boundaries. In all these cases of regular nasal harmony, nasality can be represented as a floating feature in underlying representation. This feature "docks" onto the first eligible segment counting from the left and spreads rightward in a local, segment-by-segment fashion across any and all following nonobstruents. (We shall see independent justification for rightward directionality of spreading in section 3.2.2.) In these examples, there is no obstruent to stop its passage. Note that *m* and *n* in words like *mɔ̰́nɔ̰̂* 'oil' are the nasalized variants of underlying /ḅ/ and /l/, respectively, following the analysis given earlier. While it is clear that *l* is not an obstruent, the status of the nonexplosive stop *ḅ* is less evident; we examine nonexplosive stops more thoroughly in section 4.

What if an obstruent is present in the nasalization domain? If it is the first segment in the domain, it is simply overlooked, and the nasal feature docks onto the following segment, as in the examples 'blood' and 'strong odor' in (10b). If it occurs internally in the domain, however, nasalization never spreads across it. Nasal domains containing internal obstruents give rise to one of two types of *disharmonic morphemes*. These are illustrated in (11). (V_n = nasal vowel, V_o = oral vowel, O = obstruent)

(11) a. V_nOV_o:

mà̰kɔ́	‘also’	ámṵ̀kɔ̀rɔ̀	‘cassava’
íhḭ̀gʷè	‘ax’	ɔ́ꜝmá̰nḭ̀zì	‘pity’
ḿmá̰ntɪ̀	‘small’	ákʷʊ̰́ mḛ̀kêy	‘coconut’
(áká) rìkʷʊ̰́gà	‘right (hand)’	mḭ́nḭ́ꜝvɔ́	‘saliva’

b. V_oOV_n:

bádʊ̰̀	‘human being’	ŋ̀gàdá̰	‘chair’
bíkó̰	‘please’	bísḭ́	‘poison’
m̀’ḅòfṵ́	‘padlock’	òdòkʷṵ́	‘many’
ábɔ́cá̰	‘type of sack’	rɪ̀tɛ́zá̰	‘sand’

c. V_nOV_n: no examples have been found

In the examples of (11a), nasalization cannot spread from the first vowel onto the following obstruent, since obstruents are everywhere nonnasalizable. As nasal spreading is strictly local in nature, spreading from segment to segment (rather than e.g. from vowel to vowel across consonants), it cannot skip over the obstruent. Therefore its passage is blocked. Here, then, is an example of nasal resistance as discussed at the beginning of this paper.

If a nasal morpheme contains an internal obstruent, it is unpredictable whether it is the first vowel that is nasalized, as in (11a), or the second vowel, as in (11b). While the pattern in (11a) can be predicted by left-to-right spreading of the same sort assumed for the cases of regular harmony in (10), the pattern in (11b) cannot. Given this fact, we analyze the nasal feature in the former case as a floating feature and in the latter case as a feature that is underlyingly linked to the vowel. This analysis is illustrated in (12).

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(12)  underlying:      N                       N
                                               |
                  ḅ    a    k    ɔ       b  a  d  ʊ     [bádʊ̰̀]

      surface:         N                       N
                       |                       |
                  ḅ    a    k    ɔ       b  a  d  ʊ     [bádʊ̰̀]

                  mà̰kɔ́ ‘also’ (11a)       bádʊ̰̀ ‘human being’ (11b)
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Nasalization of the vowel in the first case (11a) results from the docking of a floating feature, which is blocked from spreading rightward by the obstruent *k*. In the second case (11b), the nasality of the vowel results from an underlying specification.

The absence of morphemes containing V_nOV_n sequences in our data (11c) follows from three properties of the nasalization system: (1) only one nasal feature occurs in the lexical specification of any morpheme, (2) this feature spreads only in a local (that is segment-by-segment) fashion, and (3) obstruents cannot bear nasality. Given these properties, the configuration V_nOV_n cannot arise.

A third type of disharmonic morpheme is illustrated in (13).

(13) V_oNV_n:

óg^{w}ùmá̰gàlà	‘chameleon’	kínà̰	‘now’
m̀’ḅɔ́mà̰	‘heart’	ɛ́kìnḭ̀mà̰	‘plantain’
óḅórómá̰	‘wide road’	íbínḛ́	‘type of fruit’
àkàmʊ̰̀	‘pap’	ɔ̀sínḭ̀	‘straight ahead’

In these examples, an oral vowel V_o is immediately followed by a nasal consonant N and a nasal vowel V_n, in that order. As in the previous case (11b), we analyze the nasal vowel in these examples as bearing a lexical specification for nasality. This feature spreads rightward across vowels and any nonobstruent consonants, as in the case of 'plantain'.

Given this analysis, we might also expect to find cases of disharmonic morphemes in which an oral vowel is followed by an approximant and a nasal vowel, such as a hypothetical form **bárʊ̰̀.* Such forms do not occur in our data. As there is no evidence beyond the distributional gap itself for a synchronic process of regressive nasalization across syllable boundaries, we propose to exclude such forms by a static constraint prohibiting oral vowels before nasalized approximants: $*V_oA_n$ in the phonological root.

To summarize, we have seen that Ikwere has a system of nasal harmony at the morpheme level. Any morpheme either does or does not bear a feature of nasality in its lexical representation. If it is present, this feature either floats (examples (10), (11a)) or is linked to a noninitial vowel (examples (11b), (13)). In either case, its distribution across the morpheme is fully predictable. If it is not already linked, the feature associates to the first nonobstruent counting from the beginning of the domain (the phonological root), and then spreads rightward in a segment-by-segment fashion till it reaches an obstruent or the end of the morpheme. Since spreading operates in long-distance fashion in polysyllabic morphemes, crossing syllable boundaries, the two criteria for recognizing nasal harmony at the morpheme level (3a,b) are satisfied.[2]

3.2.2. Nasal harmony at the word level

We next consider nasal harmony at the word level. Here we will show that nasal harmony in Ikwere creates a regular pattern of alternation between oral and nasal variants of suffixes, satisfying the third criterion (3c) for nasal harmony.

Nasalization spreads progressively across morpheme boundaries in certain suffixed forms. In nouns, nasal harmony has few opportunities to operate due to the near-absence of suffixes. There appears, however, to be a noun-forming derivational suffix *-rV*, where *V* represents a copy vowel. This vowel regularly harmonizes in nasality with the preceding vowel, as is shown by the examples in (14):

(14) í-bè-rè ‘belch’ (cf. è-bě í-bè-rè ‘to belch’)
ó-kò̰-ró̰ ‘stubbornness’ (cf. ò-kǒ̰ ó-kò̰-ró̰ ‘to persist in seeking revenge’)

Nasalization here could be regarded either as an effect of nasal harmony or of the vowel copy rule itself, which could be understood as copying all features of the preceding vowel, including its nasality.

Word-level nasal harmony is most evident in verbs, where it applies to all true suffixes, as opposed to verb roots occurring as the second member of compound verbs. Nasal harmony is illustrated by the suffixes *-lEm* (from underlying /lEḅə̰/) and *-rU* in the examples in (15). (In these and later examples, upper-case letters indicate vowels whose surface value is determined by ATR vowel harmony.)

(15)	*-lEm:*	ò rí-lém̀	‘s/he has eaten’ (cf. è-rí ‘to eat’)
		ɔ̀ wɔ̰́-nɛ̰́m̀	‘s/he has drunk’ (cf. ɔ̀-wɔ̰́ ‘to drink’)
	-rU:	ɔ̀ byà-rʊ̀ nʊ̰̀ èkílé	‘s/he came yesterday’ (cf. à-byâ ‘to come’)
		ɔ̀ wɔ̰̀-rʊ̰̀ má̰ꜜyá̰	‘s/he drank some wine’ (cf. ɔ̀-wɔ̰́ ‘to drink’)

Nasalization is always blocked by obstruents, as is illustrated by the examples in (16), in which the suffixes begin with obstruents:

(16)	*-gʷU:*	ò kḛ̀-gʷù	‘s/he is holding’ (cf. è-kḛ́ ‘to hold’)
	-sI:	tḛ́-sí	‘dance (and let people see)!’ (cf. è-tḛ́ ‘to dance’)
	-tE:	bó̰-tě ńsḭ̀	‘listen!’ (set your ears towards s.o.)

In contrast, verb roots occurring as the second member of compound verbs do not undergo nasal harmony, even when beginning with nonobstruent sounds. This is shown in (17):

(17)	*-la:*	ònṵ̀-lá	‘to chase away’ (cf. the verb root -lâ ‘go back home’)
	-wa:	àdà̰-wâ	‘to fall breaking’ (cf. the verb root -wâ ‘break’)
	-hʷe:	ò zḛ́-hʷè-lém̀	‘s/he goes too often’ (cf. the verb root -hʷě ‘go beyond’)
	-ḅu:	ɔ́ dà̰-ḅú-lém̀	‘s/he fell down hard’ (cf. the verb root -ḅú ‘kill’)

The last examples show that the normally harmonizing suffix *-lEm* remains oral after oral suffixes, even though the roots themselves (*zḛ́, dà̰*) bear nasal vowels.

Finally, some suffixes contain inherent nasal vowels. These suffixes trigger nasalization of a following suffix vowel, but not of a preceding vowel, confirming that nasal harmony is exclusively progressive. An example is given in (18), showing that *-lEm* is nasalized after nasal suffix vowels, even though the root vowel is oral.

(18) *-ha̰:* ɔ̀ lá-hà̰-nɛ̰́m̀ ‘s/he has gone again’

As before, obstruents block the spread of nasalization both within and across suffixes:

(19) *-tE:* ɔ̀ gá-hà̰-tɛ̀-lɛ́m̀ ‘s/he has gone around’

4. What characterizes the class of nasalizable segments in Ikwere?

Let us now consider the feature analysis of the two nonexplosive stops *ḅ* and *’ḅ* more closely. We have seen that these stops pattern with sonorants in the system of nasal harmony. This is somewhat surprising, since oral stops would not be considered sonorants under most definitions of this feature. However, if they were obstruents, it would be hard to explain why they fail to pattern with other obstruents. We shall see evidence in this section that from a phonetic point of view, these sounds are not obstruents at all. Nasal harmony can therefore be stated as applying to the natural class of nonobstruent sounds. (The next section will argue that they are not sonorants either.)

The feature [±obstruent] is defined as follows by Stevens (1983, 254):

> Another class of consonants, called *obstruent*, is defined in the articulatory domain by the presence of a pressure increase within the vocal tract during production of the consonant. This pressure increase occurs because a complete closure or a sufficiently narrow constriction is made within the vocal tract to contain the air.
>
> The acoustic consequence of this pressure increase is that turbulence noise is generated in the vicinity of the constriction at some point during production of the sound. This noise can occur either throughout the constriction interval (as in a fricative consonant) or at the release of a closure (as in a stop consonant) (...). Presumably, a listener is sensitive to the presence or absence of this type of noise in the sound, and this attribute, then, defines the natural class of obstruent consonants.

Given this definition, which is followed by Halle (1992) and others, in order to determine whether any given sound is an obstruent we must find out whether it involves a buildup of air pressure behind the closure.

To see how this definition applies to Ikwere sounds, the authors conducted air pressure measurements at the Phonetics Laboratory of the University of Paris 3 using the PCQuirer system (SciCon, Los Angeles). Air pressure variation in the anterior oral cavity is measured by introducing a thin plastic tube into the side of the mouth behind the rear molars so that its open end points toward the center of the oral tract. The other end of the tube is passed through an oral mouth mask and connected to a pressure transducer. This device measures static air pressure behind labial and coronal constrictions. (An additional tube passed through the nasal cavity into the pharynx would be required to detect air pressure variation in velar stops. As the sounds of interest here, *ḅ* and *'ḅ*, are labial sounds produced with no velar closure, this additional tube was not used.)

After a pilot study was run using English words, selected Ikwere words were spoken by one of the authors, SO, a native Ikwere speaker. For each word, oral airflow and oral air pressure traces were synchronized with the audio signal as an aid to segmentation. Figures 1 and 2 show results for representative productions of *b*, *ḅ*, *p*, and *'ḅ*. In these figures, egressive airflow is shown by a rise of the oral airflow trace, and ingressive airflow by a fall. An increase in oral air pressure is shown by a rise of the oral pressure trace, and a decrease by a fall. Figure 1 presents data for *b* and *ḅ* in the words *àbá (ézè)* 'to become rich' and *àḅá (ɛ́fɔ́)* 'to run.'

(Figure 1 about here)

The explosive stop *b* (top) shows a brief burst of egressive airflow at its release (oral airflow line), lasting for two or three glottal pulses. The oral pressure line shows that air pressure builds up during the stop occlusion, peaks at release and then drops quickly at the onset of the vowel. In contrast, *ḅ* (bottom) shows no release burst, nor does it show any increase in oral air pressure during occlusion.

Figure 2 presents traces for *p* and *'ḅ* in the words *àpá (ólú)* 'to climb' and *è'ḅé* 'to pray'.

(Figure 2 about here)

As with *b*, the voiceless stop *p* (top) shows a burst of egressive air at its release and a buildup of oral air pressure during occlusion, peaking just before release. In contrast, *'ḅ* (bottom) presents a pattern similar to that typically found in implosive sounds, especially in citation form productions: an ingressive airstream at release, and a sharp drop in oral air pressure just before release.

Following the definition of obstruence proposed by Stevens (1983), then, Ikwere *ḅ* and *'ḅ* are nonobstruents: both lack an increase in oral air pressure during the occlusion, both lack an explosive release, and neither shows the major acoustic property of obstruent stops: turbulence noise at release. These sounds are somewhat unusual, given that oral stops are most commonly realized as explosives across languages. How is air pressure controlled in these stops so as to prevent a burst from occurring at release? One common method of eliminating air pressure buildup in oral stops is to lower the larynx, which expands the oral cavity. However, a close study of videotaped productions of these consonants reveals that this mechanism is not used in Ikwere. Instead, these sounds are produced by protruding the lips, which increases the volume of the oral cavity, and by laxing the lips and cheeks, which allows passive expansion of the vocal cavity as air pressure builds up within it. These compensatory gestures appear sufficient to keep air pressure from building up behind the labial closure. In addition, the glottalization of *'ḅ* prevents airflow from entering the oral cavity during most of the stop phase of this sound, further limiting the amount of pressure buildup above the larynx. See Clements & Osu (2002) for fuller discussion of the phonetic properties of these two sounds.

We conclude, then, that the Ikwere stops *'ḅ* and *ḅ* are members of the natural class of [-obstruent] stops, characterized by the absence of air pressure buildup behind the oral closure and by the resulting absence of turbulence noise at their release. These stops pattern as a natural class with sonorants in undergoing nasal harmony. Similar patterns are observed quite widely in West African languages, in which implosives and other varieties of nonexplosive stops are commonly observed to undergo nasalization in nasal vowel contexts (see, for example, data from Ijo dialects published in Williamson 1987).

The resistance of obstruents to nasalization is explained phonetically by the incompatibility of the increase in oral air pressure required for obstruent production with the velum lowering required for nasalization (Martinet 1955: 116, Ohala & Ohala 1993: 227-231). Lowering the velum allows air to escape through the nasal cavity, and thus equalizes air pressure inside and outside the mouth. The restriction of nasal harmony to the class of nonobstruent sounds is therefore phonetically motivated. It can be expressed in terms of the constraint *NO (*[+nasal, +obstruent]), cf. Pulleyblank (1989).

5. [±obstruent] in distinctive feature theory

Let us now consider the status of the [±obstruent] and its counterpart [±sonorant] in distinctive feature theory. These have traditionally been regarded as terminological variants of the same feature, with values reversed. In the more recent literature, it has been argued that this feature can be replaced with a feature of spontaneous voicing.

We argue against both of these views here. Examining first a proposal by Piggott (1992) and Rice (1993) to replace the feature [±sonorant] with an alternative feature [spontaneous voicing], we show that spontaneous voicing can be regarded as a manifestation of the more basic property of nonobstruence. We then argue, following proposals by Stewart (1989) and Clements & Osu (2002), that [±obstruent] is a different feature from [±sonorant], having a distinct phonetic definition and distinguishing sounds with different phonological properties. Finally, we consider the place of [±obstruent] in the feature hierarchy, and argue that it is a root node feature just like [±sonorant].

5.1. Obstruence and [spontaneous voicing]

In separate but related studies, Piggott (1992) and Rice (1993) have proposed to eliminate [±sonorant] in favor of a feature [spontaneous voicing], defined by Piggott (p. 48) as "a vocal tract configuration in which the vocal cords vibrate in response to the passage of air".[3] This feature is used to characterize a new class of "sonorant obstruents", which includes pre-nasalized stops and other sounds which superficially resemble obstruents but which pattern with sonorants in a number of respects, including their tendency to undergo nasalization in nasal harmony systems.

On the basis of the preceding discussion, it seems likely that [spontaneous voicing] and [-obstruent] refer to the same class of sounds. Spontaneous voicing in the original sense of Chomsky and Halle (1968) is a mechanical consequence of the absence of intraoral air pressure buildup in the production of nonobstruent sounds, provided that other necessary conditions for voicing, such as loose adduction of the vocal folds, are also present. If air pressure is allowed to build up beyond a certain threshold value, transglottal airflow is reduced to the point where the conditions for voicing are no longer satisfied unless compensatory articulatory adjustments are made. (See Clements & Osu 2002 for further discussion and references.) It follows from these considerations that speech sounds characterized articulatorily by spontaneous voicing must necessarily bear the feature [-obstruent]. In other words, [spontaneous voicing] is just another way of referring to the negative value of the feature [obstruent] as defined by Stevens (1983). Since spontaneous voicing is an effect of nonobstruence rather than its cause, [-obstruent] should be retained as the basic feature.

5.2. [±obstruent] and [±sonorant]: one feature or two?

The distinction between obstruents and sonorants has traditionally been viewed as a binary one, in the sense that all speech sounds fall into one of these two classes. In this view, [±obstruent] is simply the converse of [±sonorant], and these two features are often used interchangeably. It has been suggested by Stewart (1989), however, on the basis of a review of African language data, that the two features [±obstruent] and [±sonorant] may be two distinct features.

If [±obstruent] is defined in terms of oral air pressure buildup or its absence, how can [±sonorant] be defined? Ladefoged has proposed an acoustic definition according to which sonorant sounds are those having a periodic, well-defined formant structure (Ladefoged 1997: 615). This definition of the feature [+sonorant] applies to voiced nasals and approximants as well as vowels, but excludes oral stops (which lack a formant structure) and all voiceless sounds (which lack periodicity, i.e. voicing). This definition corresponds well to the traditional use of the term sonorant. Notice in particular that it excludes nonexplosive stops: though these sounds are usually voiced, they lack the formant structure required by the definition of [+sonorant], and are therefore [-sonorant] sounds.

In this view, then, [±obstruent] and [±sonorant] combine to yield a classification of stops into three major classes. Using the terminology of Clements & Osu (2002), these can be termed explosive stops, nonexplosive stops, and true sonorant stops, including nasal stops and perhaps laterals. These classes are characterized as shown in (20):

(20)	explosive stops	nonexplosive stops	sonorant stops
[obstruent]	+	-	-
[sonorant]	-	-	+

Under this classification, nonsonorant nonexplosive stops, such as implosives and the Ikwere sounds *ḅ* and *'ḅ*, are not obstruents but constitute an intermediate class of [-obstruent, -sonorant] sounds. This class shares many of the properties of Rice and Piggott's sonorant obstruents, such as their propensity to undergo nasalization in nasal contexts. However, by treating them as nonsonorants instead of a type of sonorant we can directly explain the fact that they fail to pattern with sonorants in many important respects; for example,

- they are not known to constitute syllable peaks;
- they never bear tonal or accentual features;
- they favor syllable onsets and disfavor syllable codas;
- they typically pattern with nonsonorant sounds in consonant clusters.

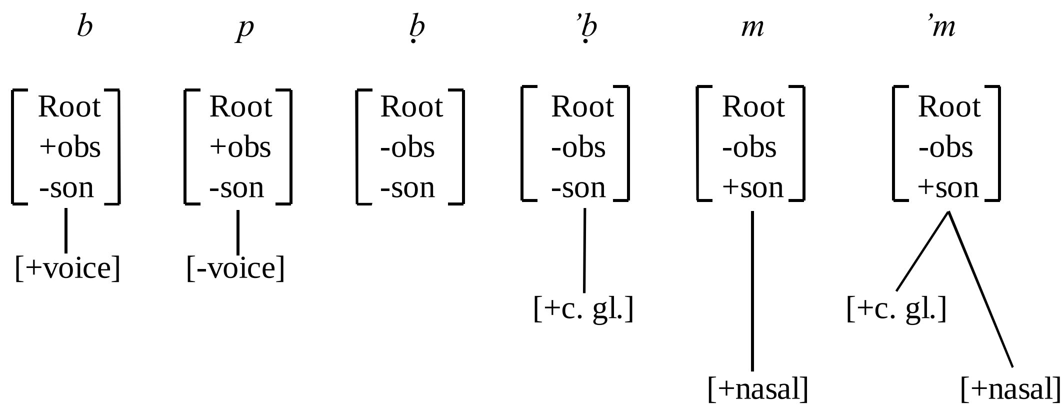
These properties may be related to the fact that nonexplosive stops, like most obstruents, are low-amplitude sounds, bearing very little "sonority" in whatever sense we might wish to give this term.[4]

5.3. [±obstruent] in the feature hierarchy

Where is [±obstruent] located in the feature hierarchy? The null hypothesis, which posits a minimum of structure in the absence of evidence to the contrary, would argue that [±obstruent] is a root node feature. That this view is correct is strongly supported by the fact that [±obstruent] does not display autosegmental effects: unlike such features as [+nasal], for example, it does not spread independently of other features, it does not trigger OCP effects, nor does it occur as a floating or contour feature. Placing [±obstruent] on an autosegmental tier of its own would incorrectly predict such effects (see McCarthy 1988 for similar arguments regarding the status of [±sonorant]).

The Ikwere consonants [b p ḅ 'ḅ m 'm] can therefore be partially represented as shown in (21), where [c. gl.] = constricted glottis:

(21)



The fact that *ḅ* and *m* (as well as *’ḅ ’m*, in their nonglottalized portions) are phonetically voiced does not require the presence of the feature [+voice]. Their phonetic voicing is a consequence of their status as [-obstruent] sounds, which, as discussed above, are realized with spontaneous voicing as long as other conditions, including an appropriate glottal configuration, are satisfied.

6. Ikwere Nasal Harmony in Typological Perspective

This final section returns to the question posed at the outset of this paper: why are some consonants more susceptible to nasalization than others? And specifically, what explains the nasal resistance scale in (1)?

The facts reviewed above argue that the scale is grounded in the property of *obstruence:* the greater the obstruence exhibited by a given segment, the greater its resistance to nasalization, and hence the lower its position on the scale. Obstruence, like sonority, is a gradient notion, in which the major division in the scale is encoded in a distinctive feature, [±obstruent].

This view explains the fact that segment classes resist nasalization to the extent that they involve more resistance to airflow, and hence more air pressure buildup in the oral cavity. Consider the following facts:

- Vowels, as the most open sounds of all, involve the least resistance to airflow
- Liquids (taps, flaps, rhotics, laterals), which offer a partial or momentary obstacle to airflow, involve more resistance to airflow than vowels
- Obstruents, as high-pressure sounds by definition, resist nasalization more than nonobstruents
- Within the class of obstruents, voiceless obstruents involve more pressure buildup than their voiced counterparts, and stops involve more pressure buildup than their fricative counterparts; thus, among obstruents, voiceless stops offer the greatest resistance to nasalization, and voiced fricatives the least

In many respects, obstruence is the converse of sonority: as one increases, the other tends to decrease. This is because the phonetic attributes of obstruence and sonorance are largely antagonistic: as obstruence increases (i.e. as oral air pressure increases), the conditions required for sonorance (periodic voicing, well-marked formant structure) decrease.

Hume & Odden (1996) have proposed that the sonority and nasalizability scales are ultimately reducible to the notion of *impedance*, defined as the resistance offered by a sound to supraglottal airflow. In this view, high-sonority sounds and those that are most susceptible to nasalization are both characterized by low impedance (low resistance to airflow), while low-sonority sounds and those that are most resistant to nasalization are both characterized by high impedance (high resistance to airflow). The fact that both scales derive from a common underlying property, impedance, would explain their similarity. It appears possible to regard intraoral air pressure as a physical diagnostic of impedance, in which case our proposal is largely convergent with that of Hume & Odden. However, we will continue to use the term obstruence, a near-synonym of impedance, here, as it more clearly relates this notion to the familiar category *obstruent*.

We suggest, then, that the nasalizability scale is better understood as an obstruence scale, which ranks segment types from most to least obstruent-like. One version of such a scale, developing proposals of Hume & Odden (1996) and Walker (1998), is defined by the ranked hierarchy of constraints shown in (22). Each constraint in the hierarchy excludes the combination of nasality with some segment class.

(22)	*Nas&VoicelessStop	>
	*Nas&VoicelessFric, *Nas&VoicedStop (variably ranked)	>
	*Nas&VoicedFric	>
	*Nas&NonObsStop	>
	*Nas&Liquid	>
	*Nas&Glide	>
	*Nas&Vowel	

The activation of one constraint in a given system implies the activation of all higher-ranked constraints. Thus, for example, if the third constraint, ruling out nasalized voiced fricatives, is active, all other nasalized obstruents are ruled out as well. Among these constraints, at least the first is assumed to be universally active, as no language is known to have phonetically nasalized voiceless obstruents (unless prenasalized stops in some languages can be analyzed in this way). The other constraints may be active or not, depending on the language and always subject to the principle that lower-ranked constraints imply higher-ranked ones. If all constraints are active, of course, there is no nasal spreading at all. This constraint hierarchy, understood as a universal, defines the nasal resistance scale in (1).

As stated in (22), the nasal resistance scale is arbitrary and requires interpretation. Here is where the notion of obstruence comes in. As we have seen, the segment types referred to by the constraints in (22) form a scale of obstruence, arranged from most to least obstruent-like. The obstruence scale itself can be defined in terms of features as shown in (23):

(23) The obstruence scale

T	D	S	Z	D<	R	Y	V	
+	+	+	+	-	-	-	-	obstruent (weight = 2)
+	+	-	-	+	-	-	-	stop
+	-	+	-	-	-	-	-	voiceless
+	+	+	+	+	+	-	-	consonantal
+	+	+	+	+	+	+	-	nonsyllabic
6	5	5	4	3	2	1	0	rank

Key: T = voiceless obstruent stops — D< = nonexplosive stops
D = voiced obstruent stops — R = liquids
S = voiceless fricatives — Y = glides (semivowels)
Z = voiced fricatives — V = vowels

The features listed at the right are those whose positive values contribute to the overall obstruence of a segment. The position of any segment on the obstruence scale is determined by the sum of these feature values. It will be noted that [obstruent], as the pivotal feature dividing all sounds into those with and without positive oral air pressure, is given a weight of 2, while all other feature values are given the weight of 1. Two segment classes, D and S, have the same rank, corresponding to the fact that they are mutually unranked on the obstruence scale in (22). The class D<, as defined here, includes nasals and perhaps laterals; whether this aspect of the classification will prove correct is one of many questions that must remain open for further study.[5]

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Notes

1. This is true in other contexts (pre-consonantally and finally) as well. See Clements & Osu (to appear) for a fuller treatment of the nasality system in Ikwere, including aspects that cannot be examined here.
2. In a variant of the present analysis, what we have treated as a floating feature of nasality would be underlyingly linked to the initial vowel. We have no purely descriptive reasons for choosing the floating feature analysis over this alternative. Under either analysis, it remains true that each morpheme bears at most one feature of nasality, which is linked to at most one vowel in underlying representation, which is the essence of our claim.
3. It is not clear to us how this definition is meant to distinguish sonorant obstruents from ordinary voiced obstruents, whose voicing results from the same conditions.
4. We do not claim that all stops that nasalize in nasal harmony systems are necessarily nonobstruents in the synchronic phonology, even in systems (such as those of Barasana and Guaraní) in which voiceless stops are transparent. Even voiceless obstruents are known to nasalize in certain contexts in some languages. Whether a given stop is obstruent or nonobstruent from a phonetic point of view can only be determined by conducting the appropriate physical experiments.
5. The classification of nasals next to obstruents is supported by Inor, in which nasal consonants behave like obstruents in blocking nasal spreading (Glachant 2000). Another open question concerns the status of laryngeals, *h* and *ʔ*. In a not uncommon pattern, also illustrated by Inor, *h* blocks nasal spreading while *ʔ* permits it.

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Figure legends

Figure 1. Airflow traces (middle line) and air pressure traces (bottom line) for *b* and *ḅ* in the words *àbá* and *àḅá*. Egressive airflow is shown by a rise of the airflow trace above the baseline. Increase in air pressure is shown by a rise in the air pressure trace above the baseline. The top line shows the synchronized audio signal.

Figure 2. Airflow traces (middle line) and air pressure traces (bottom line) for *p* in *àpá* (a) and *'ḅ* in *è'ḅé* (b). The interpretation of the traces is as for Figure 1.