Complexity in Phonological Systems

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Phonological complexity has been the subject of many discussions for a century, e.g. Zipf (1949) and more recently Pellegrino et al. (2009).

However, even though there is an agreement in seeing phonological systems as complex adaptive systems, we are still far from able to measure phonological complexity.

Factors typically considered are the inherent phonetic complexity of elements in a phonological inventory, the role of combinatorial possibilities and the combination of frequency of occurrences of different elements (Maddieson 2009).

Coupé et al. (2009) emphasize that a system is said to be complex if it is structured in different levels; if the properties of the global level differs from those of the elements of the basic level and if the systemic properties cannot be derived linearly from the basic ones.

Phonetic and phonological systems reflect various types of constraints (biological, cognitive, linguistic and social) but the understanding of their interactions and integration is still quite limited.

Taking into account the various levels of phonological systems together, gestures, features, vowels, consonants, syllable, suprasegments is a possible way to start evaluating their complexity.

Do we find more allophones when there is a smaller number of phonemes? What can we learn from this?

Lindblom & Maddieson (1988)

Basic systems
Elaborate systems
Complex systems systems

(3.1) Hawaïen (Langue Austro-Tai, Hawaï) [système basique] (Pukui & Elbert 1965)

CONSONNES	Bilabiale	Dental/alvéolaire	Vélaire	Glottale	Lieu variable	Labio-vélaire
Occlusives	p		k	ʔ		
Fricatives					h	
Approximante latérale		l				
Approximante						w

VOYELLES					
Fermées	i				u
Moyenne				ọ	
Mi-ouverte		ɛ			
Ouverte			a		

(3.2) Karitiana (Langue Tupi, Brésil) [système basique] (Storto 1999)

CONSONNES	Bilabiale	Alvéolaire	Palatale	Vélaire	Glottale	Labio-vélaire
Occlusives	p	t		k		
Nasales	m	n	ɲ	ŋ		
Fricatives		s			h	
Tap		ɾ				
Approximante						w

VOYELLES											
Fermées	i	ɨ		ĩ	ɨ̃	iː	ɨː		ĩː	ɨ̃ː	
Moyennes	ẹ		ọ	ẹ̃	ọ̃	ẹː	ọː		ẹ̃ː		ọ̃ː
Ouverte		a			ã		aː			ãː	

Suprasegments : langue à accent tonal (pitch accent)

(3.3) Mangbetu (Langue Soudan Central, Congo) [système élaboré] (Demolin 1992)

CONSONNES	Bilabiael	Labio-dentale	Alvéolaire	Palatale	Vélaire	Glottale	Labio-vélaire
Occlusives	p b		t d	ɟ	k g	ʔ	kp gb
Implosives	ɓ	ɗ					
Affriquées			ts dz				
Nasales	m		n		ŋ		
Prénasalisées	mp mb	mf mv	nt nd ns nz		ŋk ŋg		
	mʙ		ntr ndr				
Trille	ʙ̥ ʙ		tr dr				
Fricatives		f v	s z				
Flap		v̆					
Approximante			l	j			w

VOYELLES	+ATR	-ATR	-ATR	-ATR	+ATR
Fermées	i	ɪ		ʊ	u
Mi-Fermées	e				o
Mi-ouvertes		ɛ		ɔ	
Ouverte			a		

Suprasegments : 2 tons

(3.4) Mandarin, Langue Sino-tibétaine, Chine [système élaboré] (Chao 1968)

CONSONNES	Bilab.	Labio-dent.	Dent.-alv	Alv.	Rétf.	Palat	Vélaire	Uvulaire	Labio-palat.	Labio-vélaire
Occlusives	p		t				k			
Occlusives aspirées	p^h		t^h				k^h			
Affriquées			ts		tʂ	cç				
Affriquées aspirées			ts^h		$tʂ^h$	$cç^h$				
Fricatives		f	s		ʂ ʐ	ç		χ		
Nasales	m			n			ŋ			
Approximantes						j			ɥ	w
Approximante latérale				l						
VOYELLES										
Fermées	i	ʏ			u					
Mi-Fermées				ɤ						
Moyenne			ɚ							
Ouverte			a a˞							

Suprasegments : 4 tons

(3.5) !xũn (Langue Khoisan, Namibie et Botswana, dialecte du nord de la Namibie)

(Adapté de Koenig 2006)

	Lb	Al	Al-Af	Pl	Lt	Al	Dt	Retr	Vl	Gl
Approximantes	w	l		j						
Fricatives	(f)			ç					x	h [ɦ]
Occlusives	p b	t d	ts dz	c ɟ ɟː	ǁ gǁ	ǀ gǀ	! g!	!! g!!	k g	'[ʔ]
Occlusives Fortis		dth							gkh	
Occlusives complexes (+ glottale)				tc' dc'	ǁ'	ǀ'	!'	!!'	kx'	
Occlusives (aspirées)	ph dh	t' h th dh		tch dch	ǁ'h	ǀ'h	!'h	!!'h	kh gh gkh	
Consonnes complexes	tx dx			tcx dxc dcx'	ǁx gǁx ǁx' gǁx' ǁh	ǀx gǀx ǀx' gǀx' ǀh gǀh	!x g!x !x' g!x' !h g!h	!!x g!!x !!x' g!!x' !!h g!!h		
Nasales	m	n		n	nǁ	nǀ	n!	n!!	ŋ	
Nasales comlpexes	mb	nd							ŋg	
Nasales aspirées	mh	nh				nǀh	n!h	n!!h		
Glottale+ nasale	'm	'n				'nǀ	'n!			
Pharyngale+nas.	qm	qn								

Voyelles	Orales	Nasales	Glottales	Pharyngales	Phar.+Nas.	Gl+Na
Fermées	i u	ĩ ũ	ḭ ṵ	uˤ	ũˤ	
Moyennes	e o		ḛ o̰	oˤ	õˤ	õ̰
Ouvertes	a	ã	a̰	aˤ	ãˤ	ã̰

Suprasegments : 4 tons

The relation between production and perception must also be considered to evaluate the complexity of sounds.

For example, clicks, which are considered as complex articulations, are in fact simple bursts or delayed released noises from a perceptual point of view, Traill (1995).

This has clear consequences on the explanation of sound change involving clicks, Traill & Vossen (1997). Elaborated articulations are distinguished from simple ones or basic modes of production in their initiation, phonation or articulation.

Karitiana (Tupi language from Brasil)

Storto (1999), Storto & Demolin (2002)

1 Pre and post oralized

/ami/ [a.bmbi] ‘house’
/kina/ [ki.dnda] ‘thing’
/eŋɨ/ [e.gŋgɨ] ‘vomit’

2 Pre oralized

/himĩna)/ [hi.bmĩ.na)] ‘roasted’
/ena/ [e.dnã] ‘pregnant’
/esɨŋa)/ [e.sɨ.gŋã)] ‘waterfall’

3 Post oralized

/ãmo/ [ã.mbo] ‘to climb’
/osẽnda/ [o.sẽ.nda] ‘waistline’
/põ.ŋgip˺/ [põ.ŋgip˺] ‘quiet’

4 Oral

/morotɨ/ [^{m}bo.ro.tɨ] ‘paca’
/neso/ [^{n}de.so] ‘mountain’
/ŋokɨp/ [^{ŋ}go.kɨp˺] ‘sun’

Storto and Demolin (2002) describe the following allophones for /m/:

[m^b]	in environments	#_Ṽ & Ṽ_Ṽ
[mb]	in environments	Ṽ_V
[bm]	in environment	V_Ṽ
[bm˺]	in environment	V_#
[bmb]	in environment	V_V
[$^m b$]	in environments	#_Ṽ
[m˺]	in environment	Ṽ_#

How to account for the pre-and post-nasalized consonants in Karitiana?

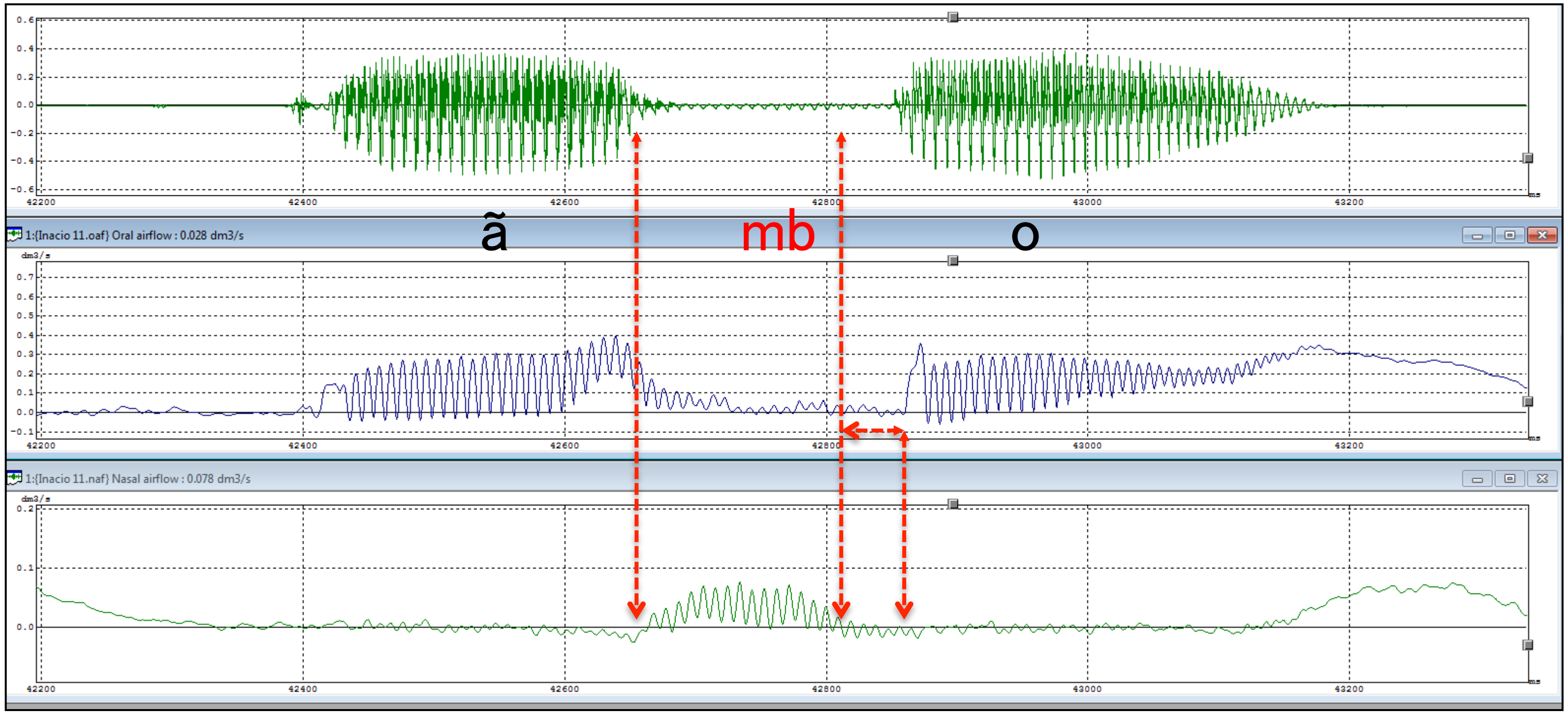
Gestures are to be taken as phonological primitives. They are elements of a dynamical system, i.e. in which time plays a crucial role.

Articulatory control

Phonetic implementation is governed by certain constraints which limit the range of possible realizations; within this range, the speaker may control the minimization of articulatory effort with maximization of perceptibility.

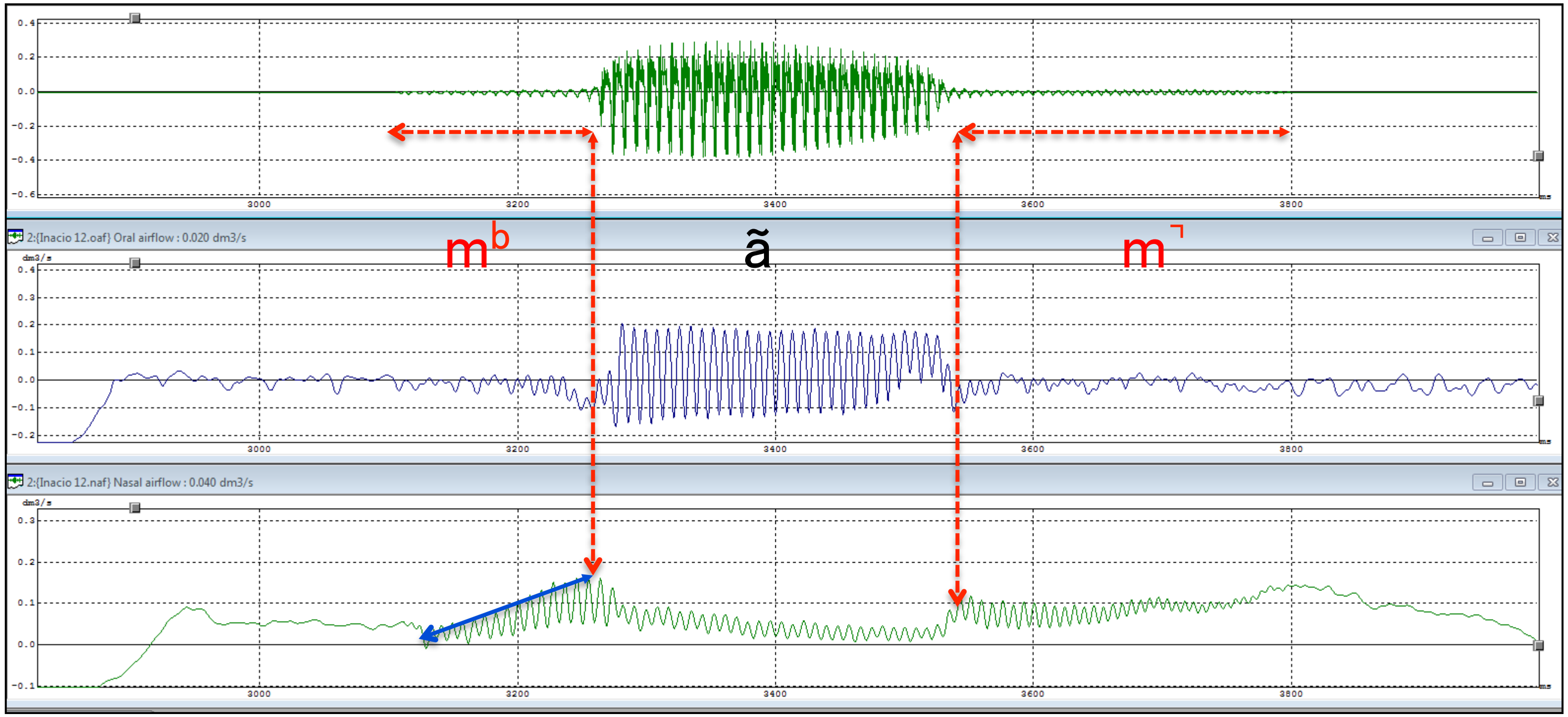
Kingston and Diehl (1994)

Post-oralized nasals

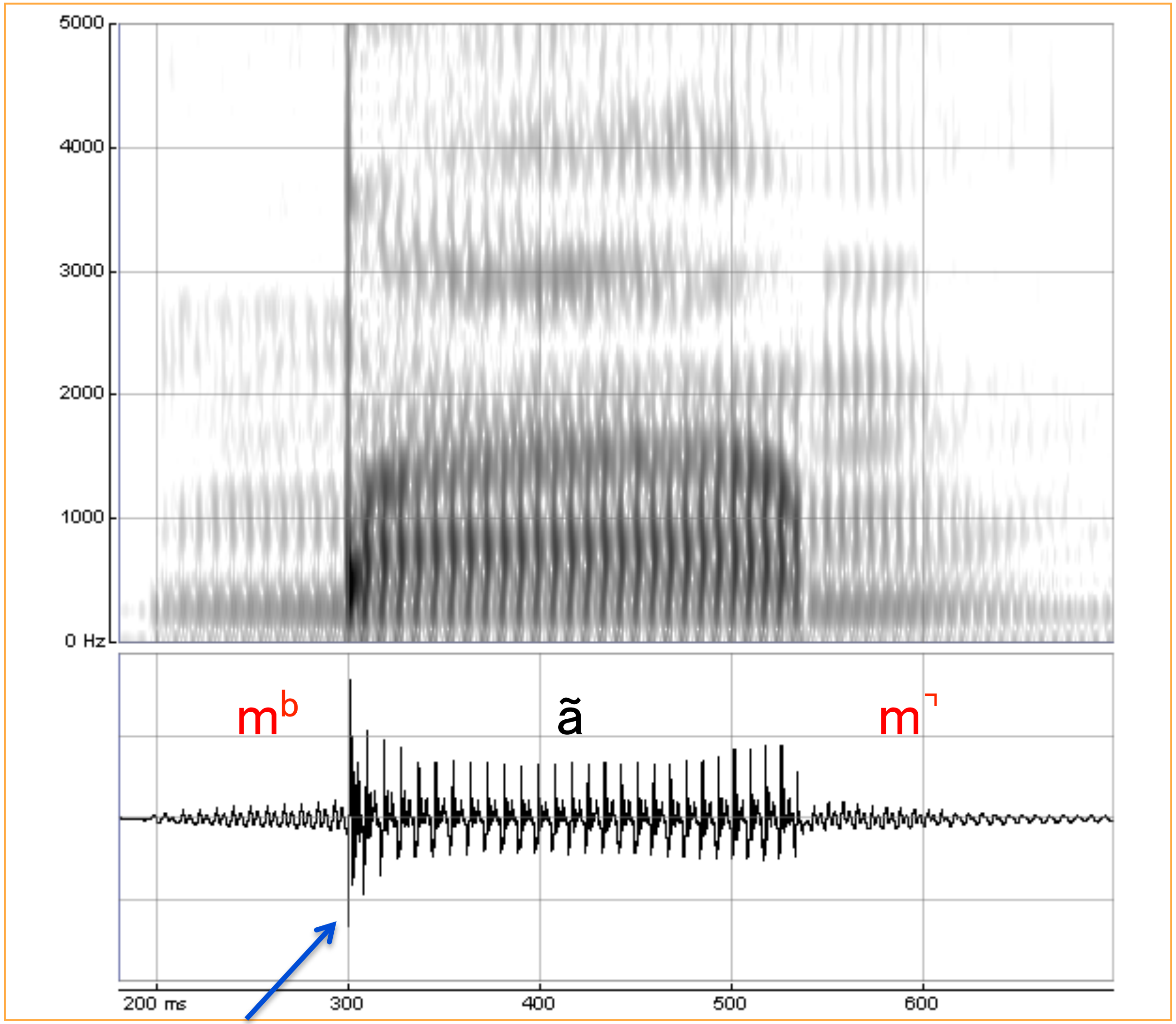


	mb	b
Duration (ms)	157.9	36
Max. Naf (dm^3/s)	0.078	-
Total vol .naf. (dm^3)	0.004	-

Post-stopped and unreleased nasals



	m^b	m˺
Duration (ms)	142	266.3
Max. Naf (dm^3/s)	0.161	0.115
Total vol .naf. (dm^3)	0.011	0.024



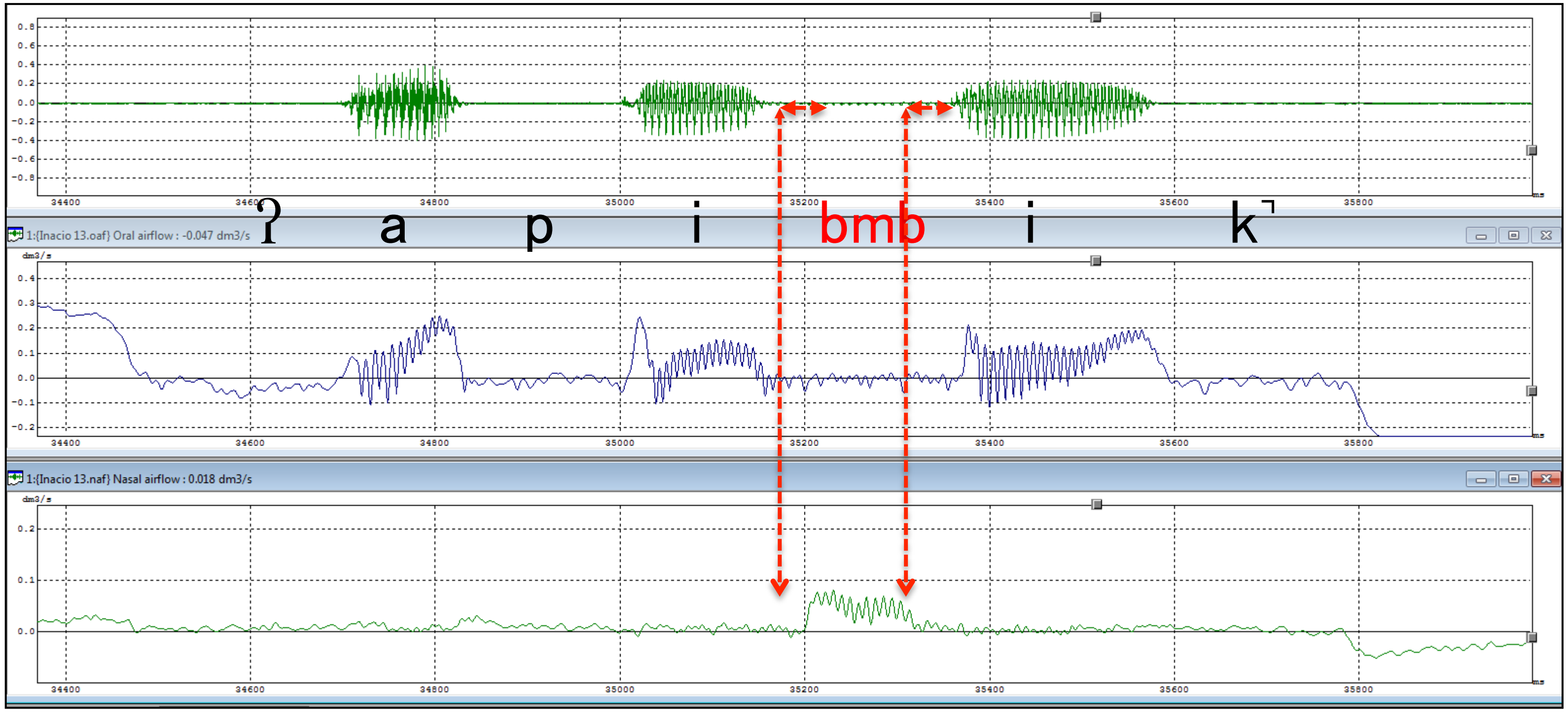
5000
4000
3000
2000
1000
0 Hz
mb
ã
m˺
200 ms
300
400
500
600

The burst in post-stopped nasals appears after an acceleration of the nasal airflow at the end of the nasal and after an increase of the Ps.

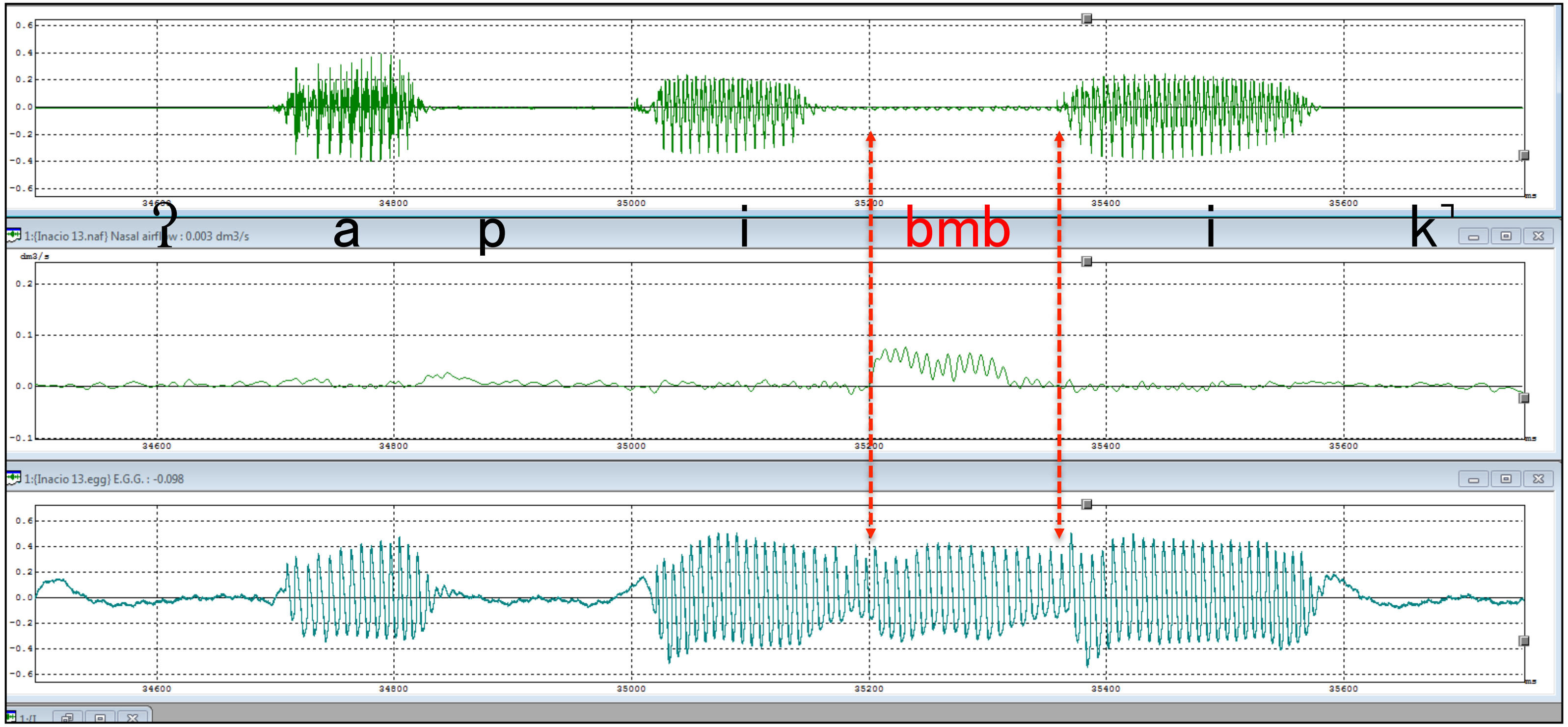
This is probably the consequence of a reduction of the back cavity provoked by a backward movement of the tongue and a lowering of the larynx.

This reduces the volume of the pharyngeal cavity and of the velum opening.

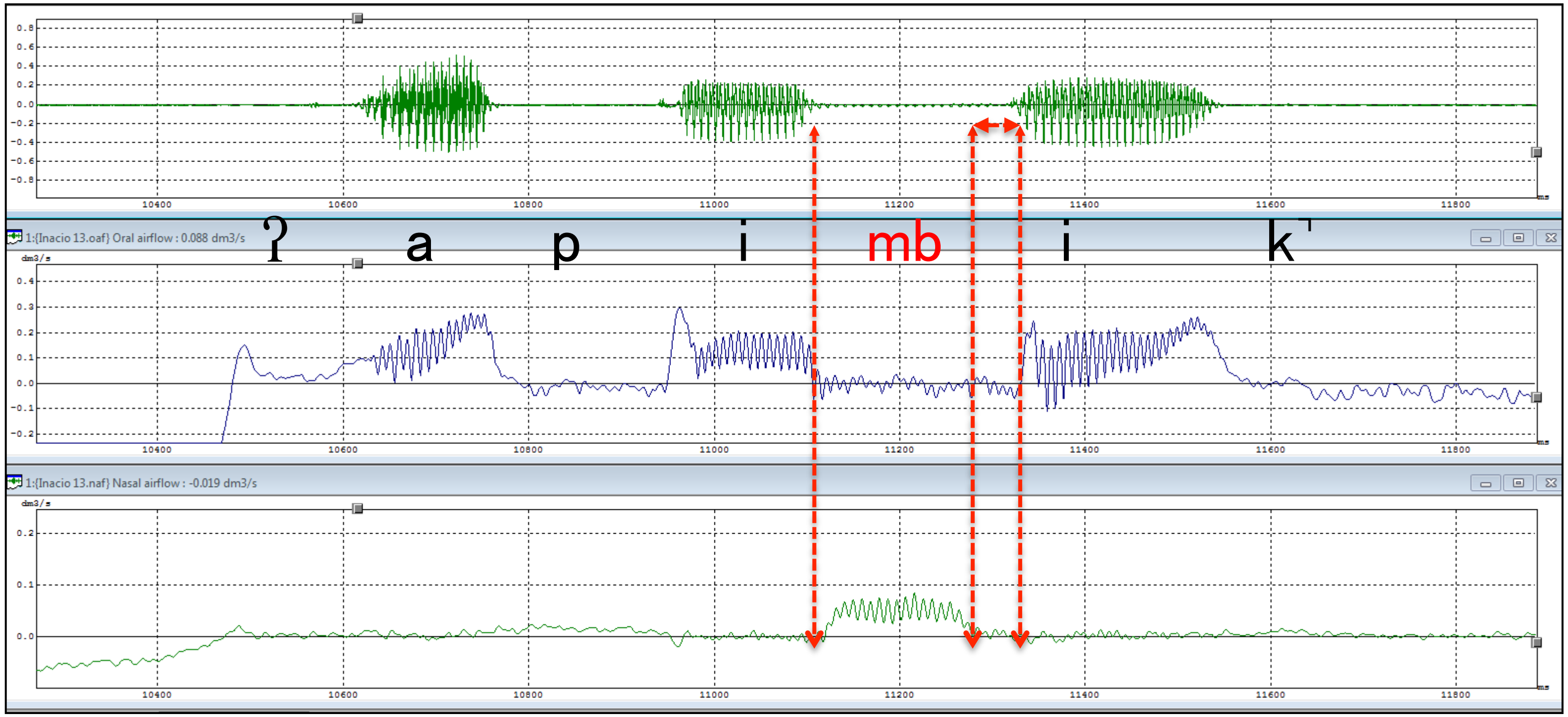
Pre- and post-oralized nasals



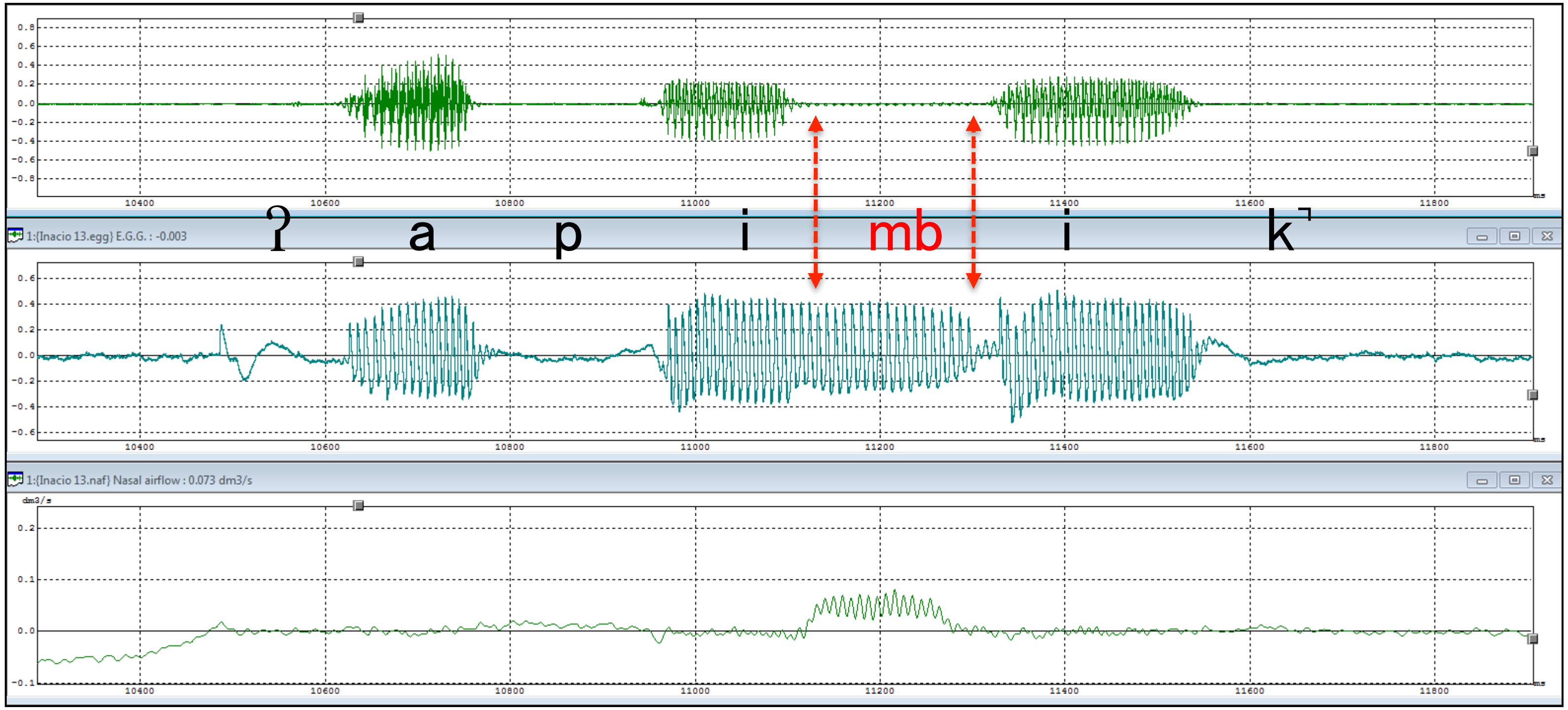
	bmb	m	b1	b2
Duration(ms)	197.2	109.1	45.5	42.6
Max. Naf (dm^3/s)	-	0.023	-	-
Total vol .naf. (dm^3)	-	0.006	-	-


ʔ a p i bmb i k˺
1:{Inacio 13.naf} Nasal airflow : 0.003 dm3/s
1:{Inacio 13.egg} E.G.G. : -0.098

Pre- and post-oralized nasals variants



	mb	b
Duration (ms)	202	42.6
Max. Naf (dm^3/s)	0.030	-
Total vol .naf. (dm^3)	0.008	-


ʔ a p i mb i k˺
1:{Inacio 13.egg} E.G.G. : -0.003
1:{Inacio 13.naf} Nasal airflow : 0.073 dm3/s
dm3/s
10400
10600
10800
11000
11200
11400
11600
11800

There is an interesting phenomenon at the transition between the oral parts of the complex nasals and the adjacent vowels, e.g. bm or mb.

The EGG signal shows a transition marked either by a damping of the EGG's signal amplitude or by a sharp transition (which likely shows some vertical movement of the larynx).

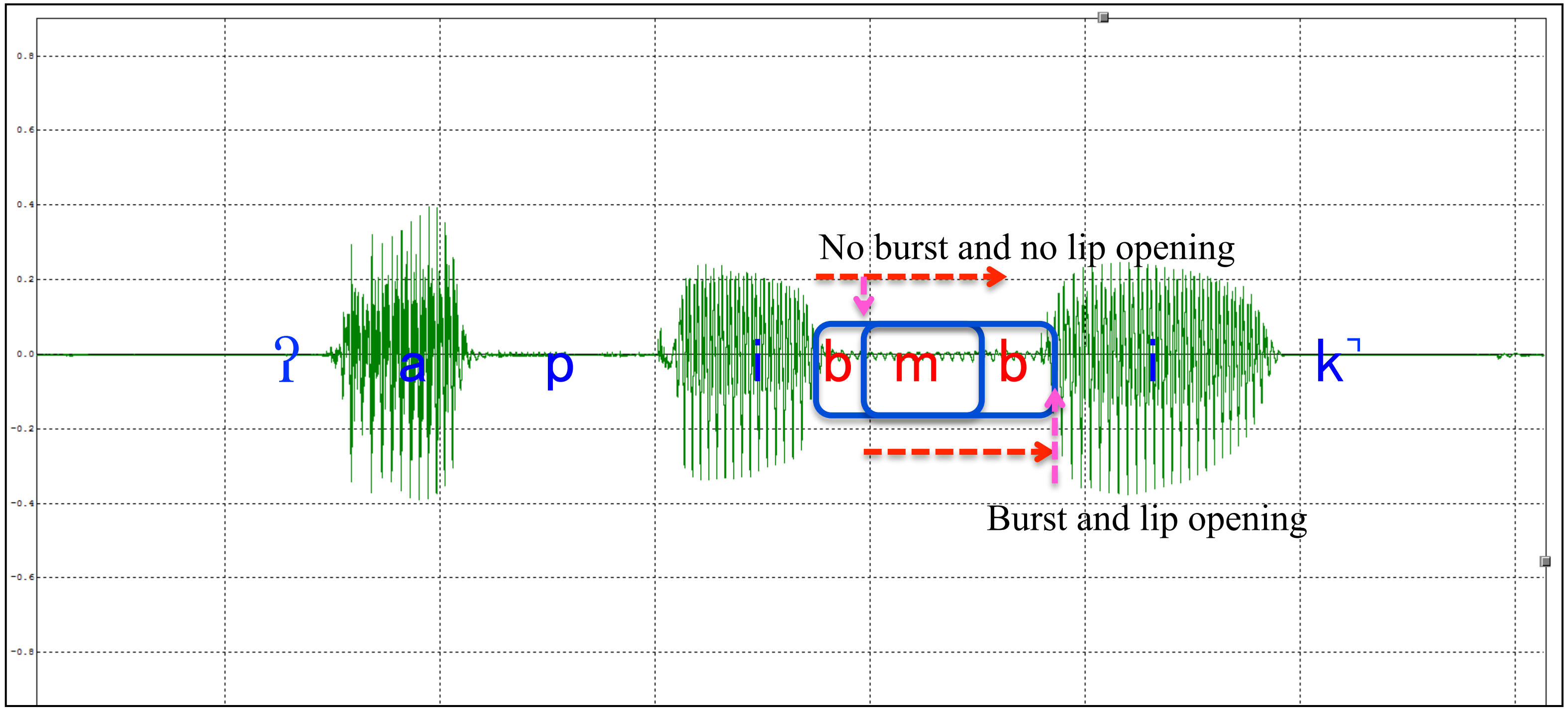
This does not happen between nasal consonants like m or n and the following nasal vowels.

A possible explanation for this is that there is no passive expansion of the vocal tract at this moment and this would create the voicing to diminish in amplitude.

Since there are no voiced stops in Karitiana, speakers would not make anything to compensate the 'voicing loss' (AVC constraint). The voiced parts (pre and post) of the complex nasals are simply a transition before or after the velum closure.

The duration of these oralized parts are on average between 30 and 40ms This is about the time for voicing to become extinct if there is no passive expansion of the vocal tract (AVC constraint).

Gestures and perception



The velum opens ‘late’ and closes ‘early’.

Hypothesis: This is to maintain the contrast between the oral character of the adajacent vowels (preceding or following).

Nasa Yuwe (Paes) Colombia

32 phonological vowels (Rojas 1998)

[i e a u]

Short/long oral/breathy/glottal/
Short/long nasal/breathy-nasal/glottal-nasal

Nasa Yuwe (Paes) vowels

Oral vowels				Nasal vowels			
i	e	a	u	ĩ	ẽ	ã	ũ
i̤	e̤	a̤	ṳ	ĩ̤	ẽ̤	ã̤	ṳ̃
iˀ	eˀ	aˀ	uˀ	ĩˀ	ẽˀ	ãˀ	ũˀ
i:	e:	a:	u:	ĩ:	ẽ:	ã:	ũ:

!xóõ (Traill 1985)

Glottalized	iˀ eˀ aˀ oˀ uˀ
Breathy and glottalized	a̤ˀ o̤ˀ ṳˀ
Breathy nasalized and glottalized	ã̤ˀ õ̤ˀ
Pharyngalized and glottalized	aˤˀ uˤˀ
Glottalized and nasalized	ˀĩ ˀã ˀõ ˀũ

San Jerónimo Tecoatl Mazatec

Vowel system

LY VAN TU (2015)

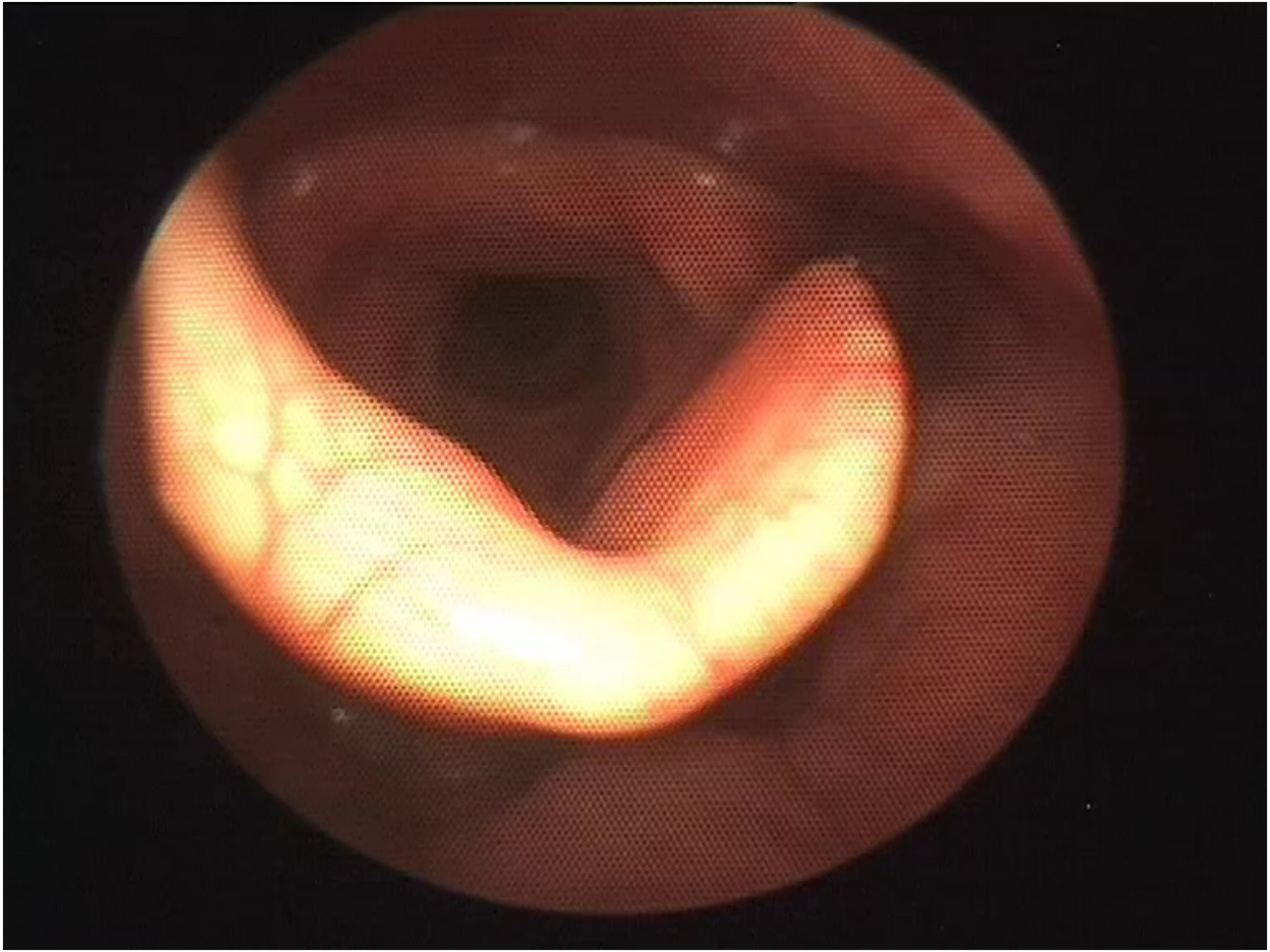
San Jerónimo Tecoatl					
Voyelles orales modales	i	e	a	o	-
Voyelles orales soufflées	i̤	e̤	a̤	o̤	-
Voyelles orales craquées	ḭ	ḛ	a̰	o̰	-
Voyelles nasales modales	ĩ	ẽ	ã	õ	-
Voyelles nasales soufflées	ĩ̤	ẽ̤	ã̤	õ̤	-
Voyelles nasales craquées	ḭ̃	ḛ̃	ã̰	õ̰	-

Contexts in Nasa Yuwe

$V^{ʔ}$__C[-voiced]
$V^{ʔ}$__C[+sonorant]
$V^{ʔ}$__#

Sometimes $V^{ʔ}V$

$V^{ʔ}$ in Nasa Yuwe? Glottalized? Laryngalized?
(interruptas, Rojas 1998)



The relation between production and perception has important consequences in evaluating the phonotactics of a system. It affects the placement of phoneme category boundaries, segmentation of nonce forms, and speed of accuracy of phoneme monitoring Hay et al. (2004).

This relies on the fact that the syllable is an organizing principle for grouping segments into sequences Zec (2007).

Phonotactic restrictions are conditioned by factors other than syllable structure.

Kanincin (Ruund) and Rwanda show that they are constrained by the coordination of gestures rather than by constraints on consonant combination, probabilities on frequency of occurrence or syllable structure.

The phase and coordination of gestures account for the apparent phonotactic constraints of Kanincin (Ruund) and other Bantu languages.

Phonotactic knowledge in unwritten languages is not driven by phonological awareness emerging from literacy.

Another way of looking at phonotactics is taking into account probabilities. It has been suggested that speakers of a language are sensitive to the statistical distribution of phonological and morphological forms in the language Frisch et al. (2000), Alderete et al. (2007).

This means that constituent combination probabilities refers to the probability of the co-occurrence of constituents, relative to their chance rate of occurrence. However, phonotactics is not just the inventory: it is how it is put together in words. What are the constraints on segmental sequences?

Kanincin (Chabiron 2013)

NCV:NC

ka: mpa:mp tête dure ou rien ne pousse

ma: mbwa:mb causerie

nda:nd coton

yi: nsa:ns le dégoût

mwi: mpa:nz

Kanincin (Chabiron 2013)

NCSV:NCS

ʒi: • mpwa:mbw des cloches

ʒi: • mbwe:mbw les flancs de ventre ramolis, bourlet

mwi: • mpwa:mpw à l'aisselle

NC and NCS in Kanincin are <u>single phonological units</u>

They are <u>complex consonants</u>

Most NCS clusters (labialized prenasalized consonants) involve a labial gesture from start to end.

NC clusters involve a single constriction gesture in the oral tract combined with a sequence of opened/closed velum gesture.

When tested with non literate speakers or in word games such clusters are treated as <u>single units</u>.

⇒ Complex consonants in Kanincin (as in other Bantu languages) are constraint by the coordination of gestures rather than by constraints on consonant combination, probabilities on frequency of occurrence or syllable structure.

⇒The phase and coordination of gestures (which can overlap) account for the apparent phonotactics constraints of Kanincin and other Bantu languages.

Phonotactic knowledge in unwritten languages is not driven by phonological awareness emerging from literacy.

In written languages, complex consonants imply sequences of segments (segmental symbols) to be symbolized.

These complex consonants reflect the combination of several non exclusive gestures.

⇒ [NCS] or [NC] whether in onset or in coda are one /C/

⇒ Speakers ‘know’ where they can be posited, i.e. in syllable onset or sometimes in coda

⇒ These languages are unwritten languages. The phonotactic knowledge of the speakers is not associated to a symbolic representation of segments.

⇒ Hypothesis :This is rather linked to the knowledge of gestural combinations (or superimposition) that trigger the correct phonetic knowledge or expected acoustic output.

The timing of articulatory movements or gestures (and their trajectories in time and the space of the VT) is crucial to understand the complexity of phonological systems.

Allophones should be treated as phonological categrories if we want to have a corrcet idea of the number of elements that are part of a system.

The relation between production and perception determines the phonetic knowledge of speeakers and also their knowledge of the phonotcatics of specific languages.

Thank

you

for

your

attention