

Acoustics & Aerodynamics of Nghlwa Implosives

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Outline

- Brief background on Nghlwa language
- Background on implosives: phonetics and phonology
 - Cross-linguistically
 - In Nghlwa
- Data and methods
- Results:
 - Acoustics of implosives vs. non-implosives
 - Aerodynamics of /b/
- Theoretical implications and next steps

Language background

- ISO [gwa]
- Spoken by the Gwa people located about 30 kilometers east of Abidjan, Côte d'Ivoire
 - Estimate of around 25,000 speakers (Blecke 2018)
 - Also known as Mbatto, Gwa
- Documentation
 - Comparative wordlist (Delafosse 1904)
 - Grammar sketch (Grassias & Bôle-Richard 1983)
 - Descriptions of aspects of the phonology and morphology (Grassias 1974, Bôle-Richard 1984, Bogny 2005, Konan & Mando 2006, Blecke 2016, 2018)



Consonant inventory

	Bilabial	Alveolar	Palatal	Velar	Labiodental	Glottal
Stop	p (b)	t d	c ɟ	k g	gb	
Fricative	f (v)	s (z)				h
Approx.	b ₁ [b, m]	l [l, n, d, r]	j [j, ɲ]		w [w, ŋm]	
Implosive	b ₂ [ɓ]	ɗ	ɟ	g	gb	

Note: the two types of /b/ reflect two different historical sources - *b > **b**₁ vs. *p > **b**₂

Proto-Potou > Nglwa consonants

Proto-Potou	Features (Stewart 1973)	Nglwa
*b, *l, *j, *w	[lenis, +voice] → <i>sonorant</i>	/b ₁ l j w/
*p ^h , *t ^h , *c ^h , *k ^h	[lenis, -voice] → <i>obstruent</i>	/p t c k/
*p, *t, *c, *k, *kp	[fortis, -voice] → <i>obstruent</i>	/b ₂ d ʃ ɡ ɡb/

Implosive as a sonorant

/b₁/ – [b] after oral vowel, [m] after nasal

(1)

á b̄

2SG break.PFV

‘You broke’

(2)

ám **m̄**

1SG break.PFV

‘I broke’

Implosive as an obstruent

/b₂/ – [b] everywhere

(3)

á b̩

2SG love

‘You love’

(4)

ám b̩

1SG love

‘I love’

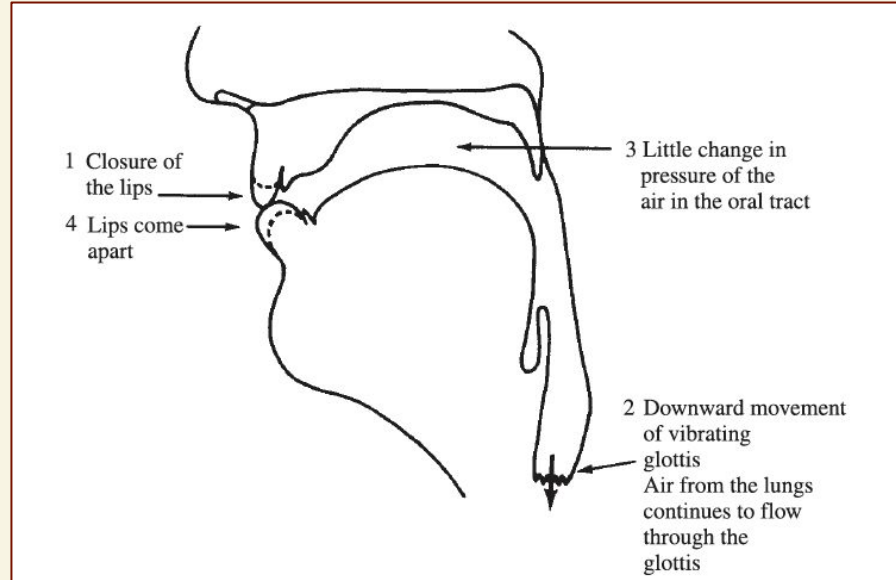
Phonetic neutralization?

Bilabial implosives in Nghlwa phonologically pattern in 2 distinct ways, based on historical source:

- /b₁/ as a sonorant (reflex of *b)
- /b₂/ as an obstruent (reflex of *p)

Question: how are they realized phonetically? Are implosives from distinct historical sources in Nghlwa phonetically distinct or phonetically neutralized?

Articulating implosives



Classically described as having a glottalic ingressive airstream mechanism

Except sometimes they don't

Problems with the classic account of implosives = glottalic ingressive consonants
(Clements & Osu 2002):

- Can be produced with no ingressive airstream and without rarefaction (negative oral air pressure)
- Can be produced with or without full glottal closure
- Can be produced with modal voicing (pulmonic egressive airstream)
- Some have even been reported to lack voicing altogether
- Larynx lowering (and other cavity-expanding adjustments) isn't unique to implosives

Varieties of implosives

- There is wide variation when it comes to the phonetic production of implosives.
 - Lex (1994): maybe implosive is the *absence* of egressive airflow
 - Ladefoged (1971): maybe implosive is the comparatively larger and more rapid descent of the glottis (so related to timing/coordination)
 - Maddieson (1984): “No measurements have been done to confirm the occurrence of oral cavity expansion by tongue movement, jaw lowering or use of the cheeks in production of implosives...”
- Appears to be a continuum from “true explosive” to “true implosive”
- Importantly, **no single (articulatory) phonetic correlate across languages**
 - Are they all really the same category?

Implosives in Potou

Stewart (1973), describing Atchan (ISO: ebr), a language very close to Nghlwa:

- “The articulatory nature of [implosives] ... appears to consist in the **absence of the heightened oral cavity pressure** which, in other languages, commonly occurs as a redundant feature of obstruents.”
- “The [implosive] stops of [Atchan] seem ... to differ from implosive stops as described by Westermann & Ward (1933) in being **merely nonexplosive rather than actually implosive.**”

Phonological patterning of implosives

A recent typological survey (Sande & Oakley 2023) looks at a sample of 95 languages and finds that implosives pattern phonologically:

- with sonorants in a third of languages
- with obstruents in a third of languages
- with 'mixed' patterning in a third of languages

However, articulatory studies are rare – unclear if these distinct phonological categories are reflecting phonetic differences.

Research questions

1. What do implosives in Nghlwa look like...
 - articulatorily: are they produced with or without rarefaction?
 - acoustically: what are their phonetic correlates?
2. Are there consistent differences between /b₁/ and /b₂/?

Data & methods

Elicitation sessions with 2 speakers in Abidjan, Côte d'Ivoire



Acoustics: 392 tokens from 2 speakers

- Zoom F2-BT field recorder with lavalier mic



Aerodynamics: 50 tokens from 1 speaker

- Laryngograph EGG-D800 with airflow mask attachment

Acoustic tokens

p	b	ɸ	d	ɗ	c	ɟ	ʃ	g	ɡ	gb	ɡɸ
36	18	144	22	25	7	19	20	27	49	23	1

*p 43
*ɸ 65

Aero tokens

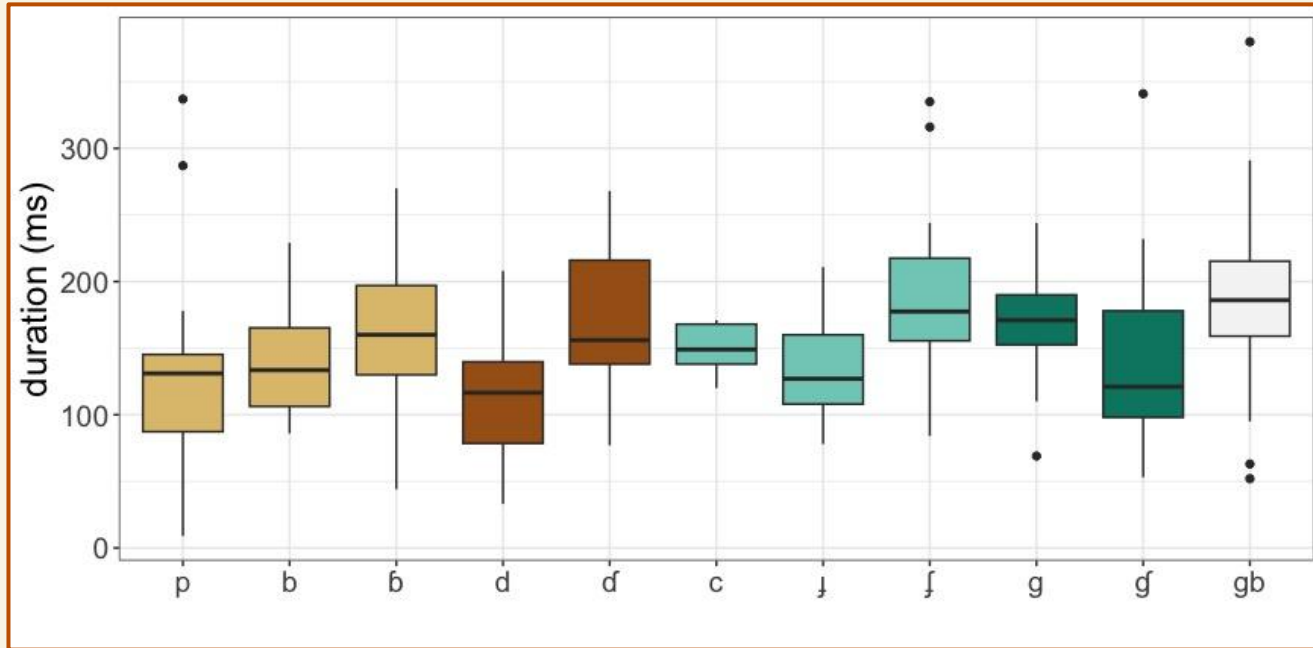
p	b	ɸ	gb	ɡɸ
17	2	21	10	0

*Labiovelar implosive /ɡɸ/ will be excluded from analysis

Methods

- All files were transcribed and annotated using ELAN and then further hand-segmented phoneme-by-phoneme in Praat (Boersma & Weenink, 2024)
- Wrote and ran Praat scripts to measure:
 - Duration
 - Mean intensity
 - Intensity contour
- Qualitatively assessed:
 - Presence or absence of rarefaction in oral pressure signal

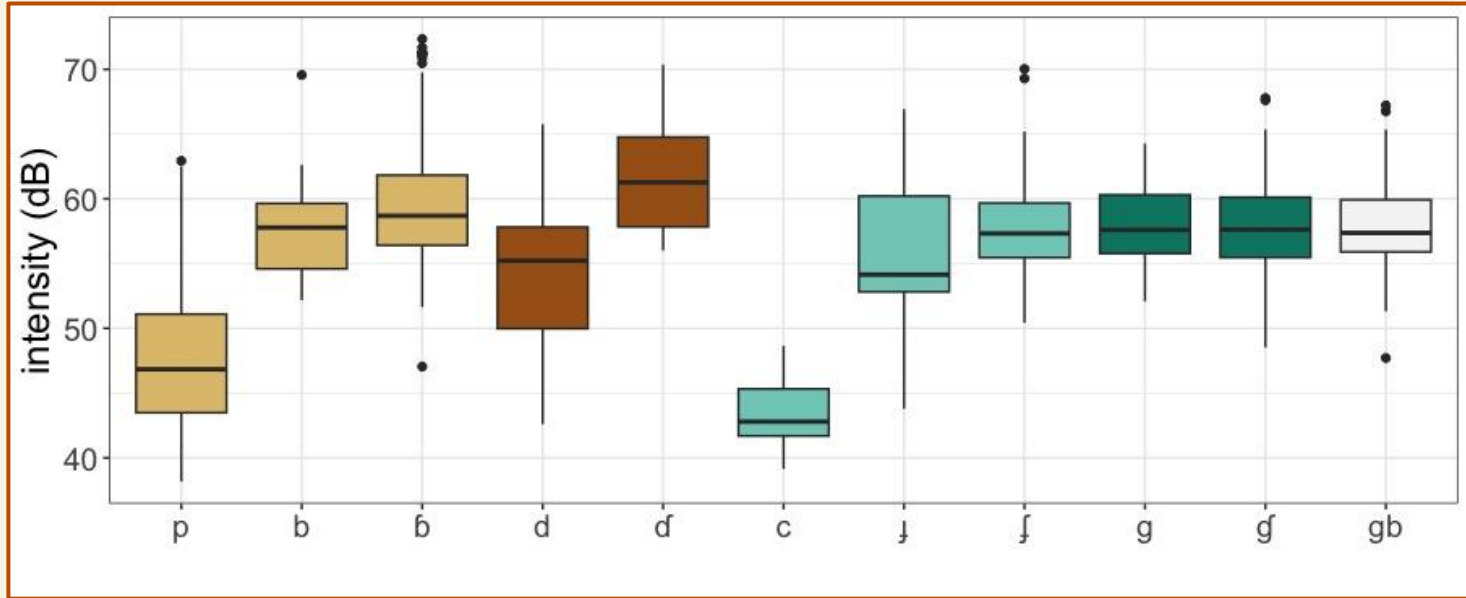
Results: mean duration



Implosives: 159 ms

Non-implosives: 143 ms

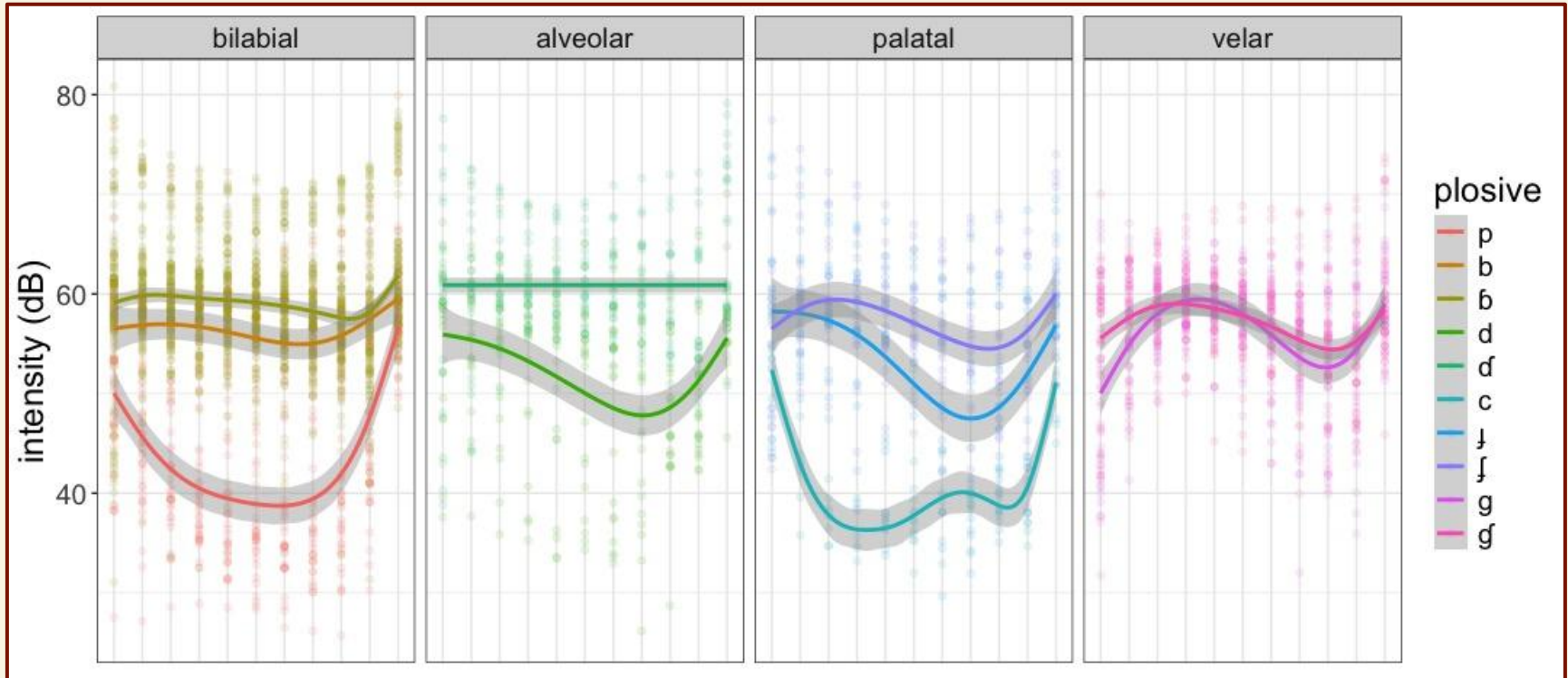
Results: mean intensity



Implosives: 59 dB

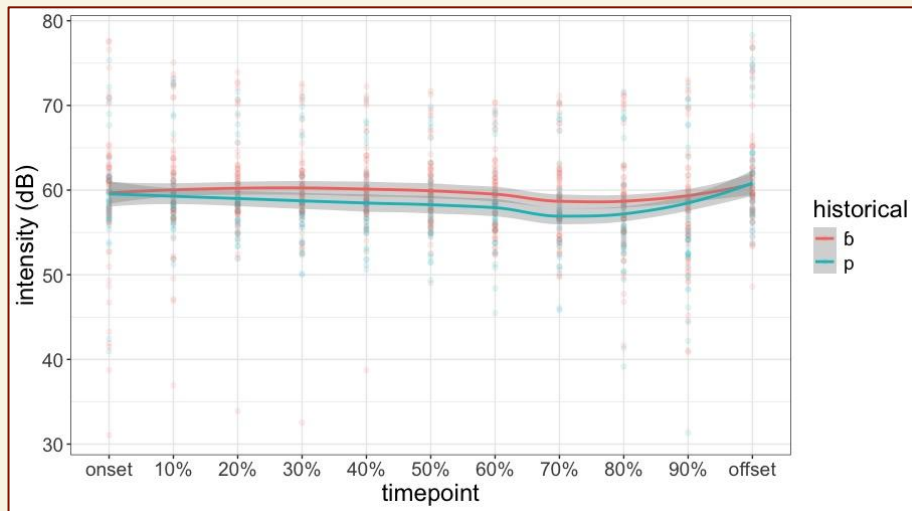
Non-implosives: 54 dB

Intensity contours

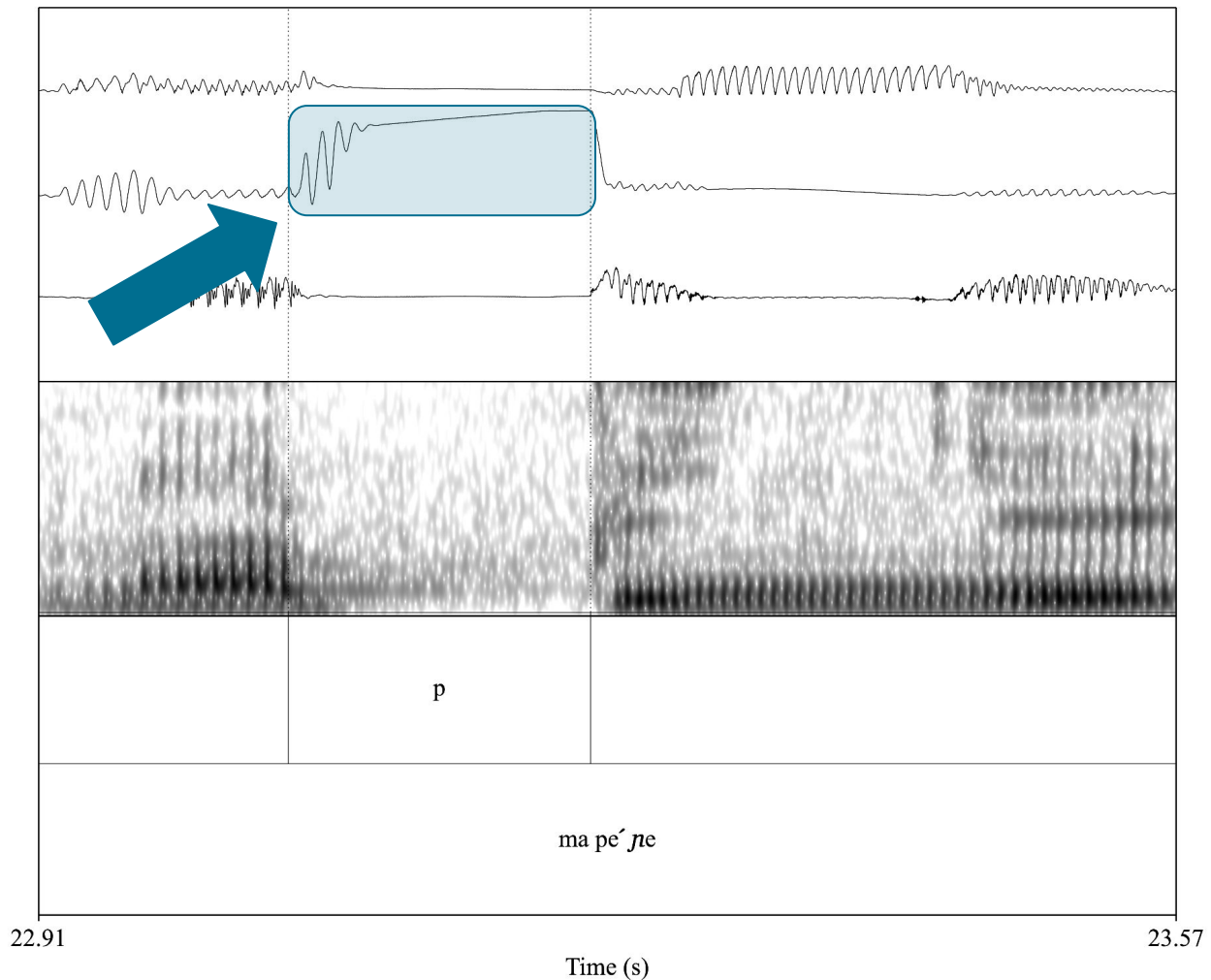


/b₁/ vs. /b₂/

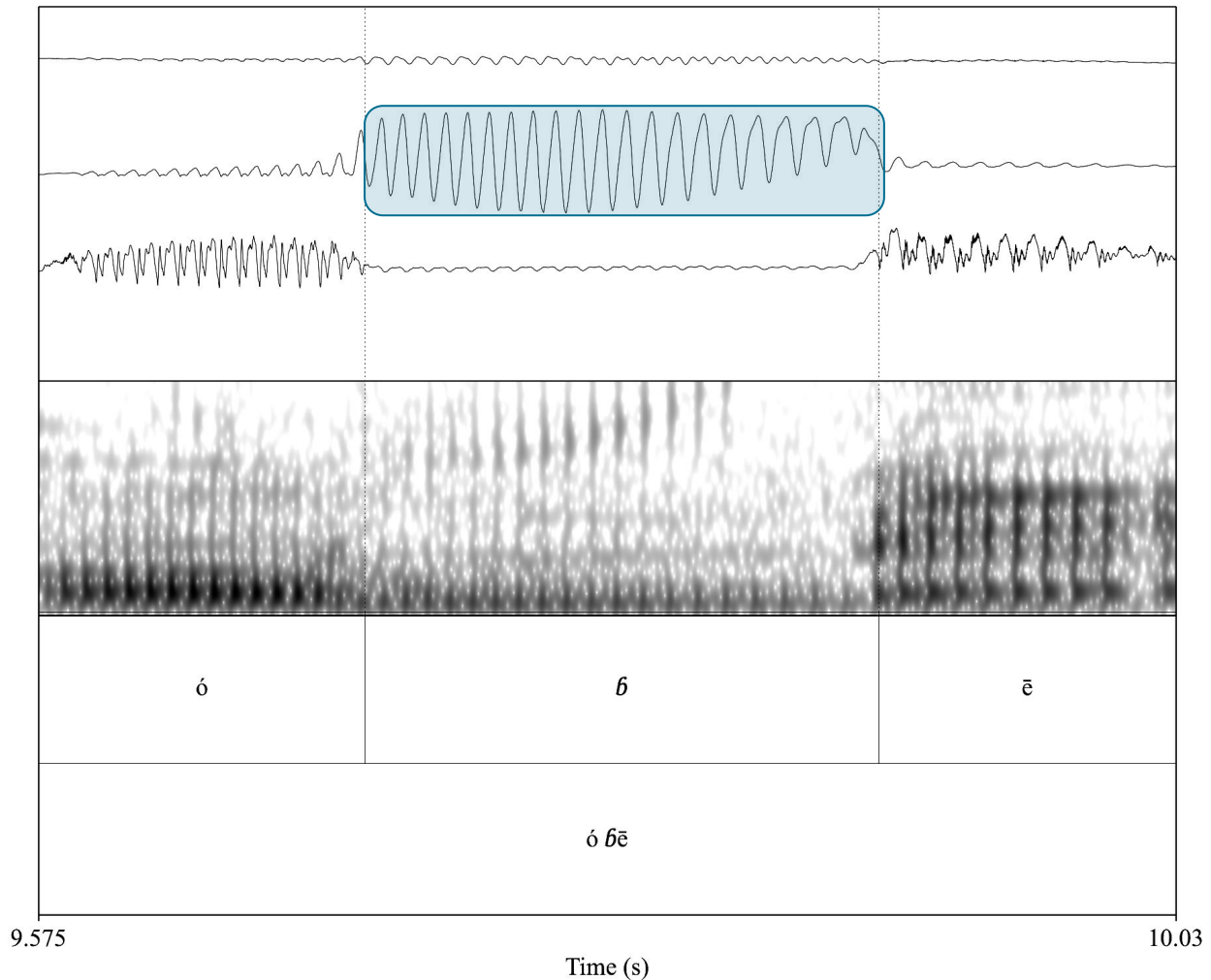
	source	tokens	mean duration	mean intensity
/b ₁ / as a sonorant	*b	65	165 ms	60 dB
/b ₂ / as an obstruent	*p	43	154 ms	59 dB



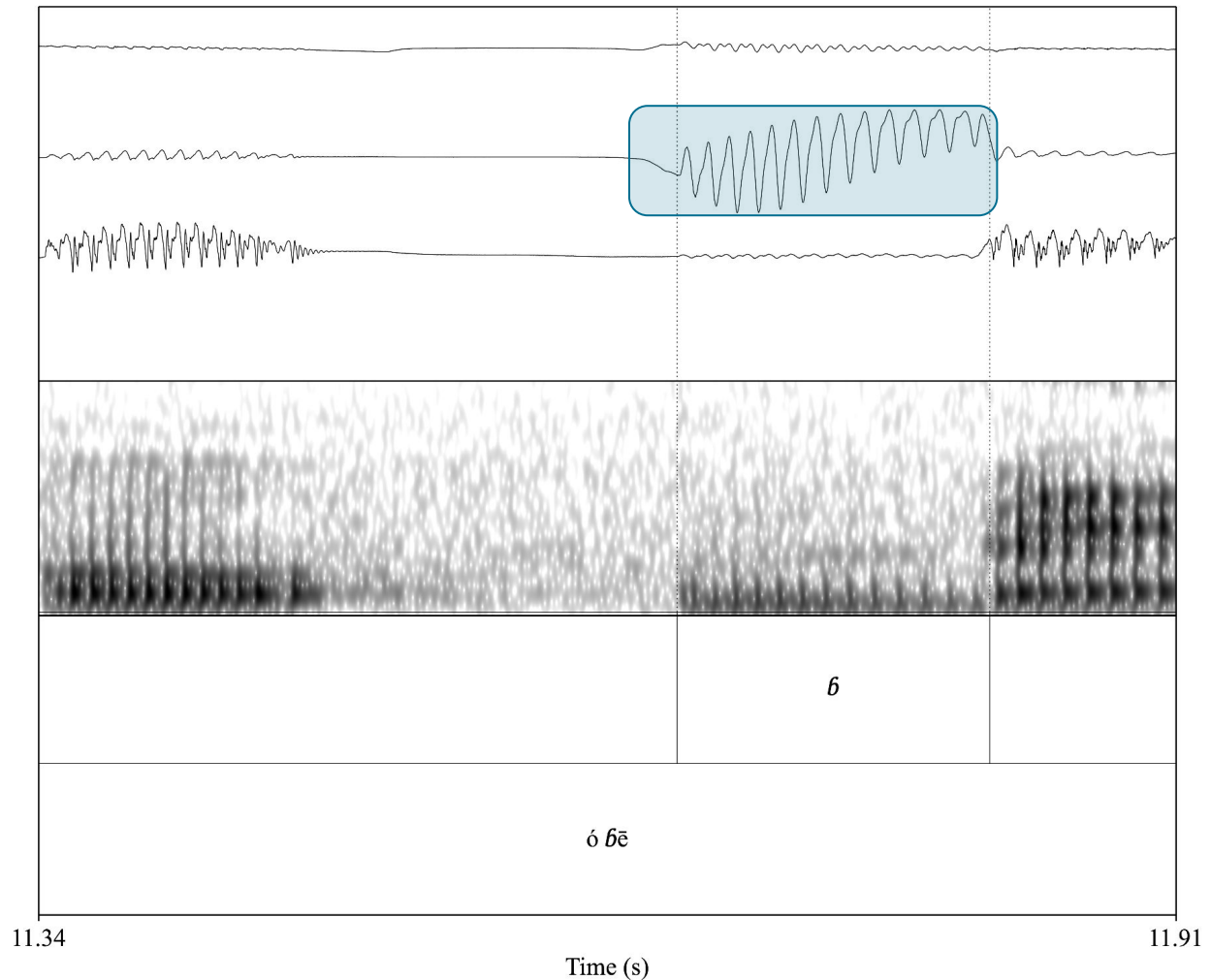
nasal flow
oral pressure
oral flow



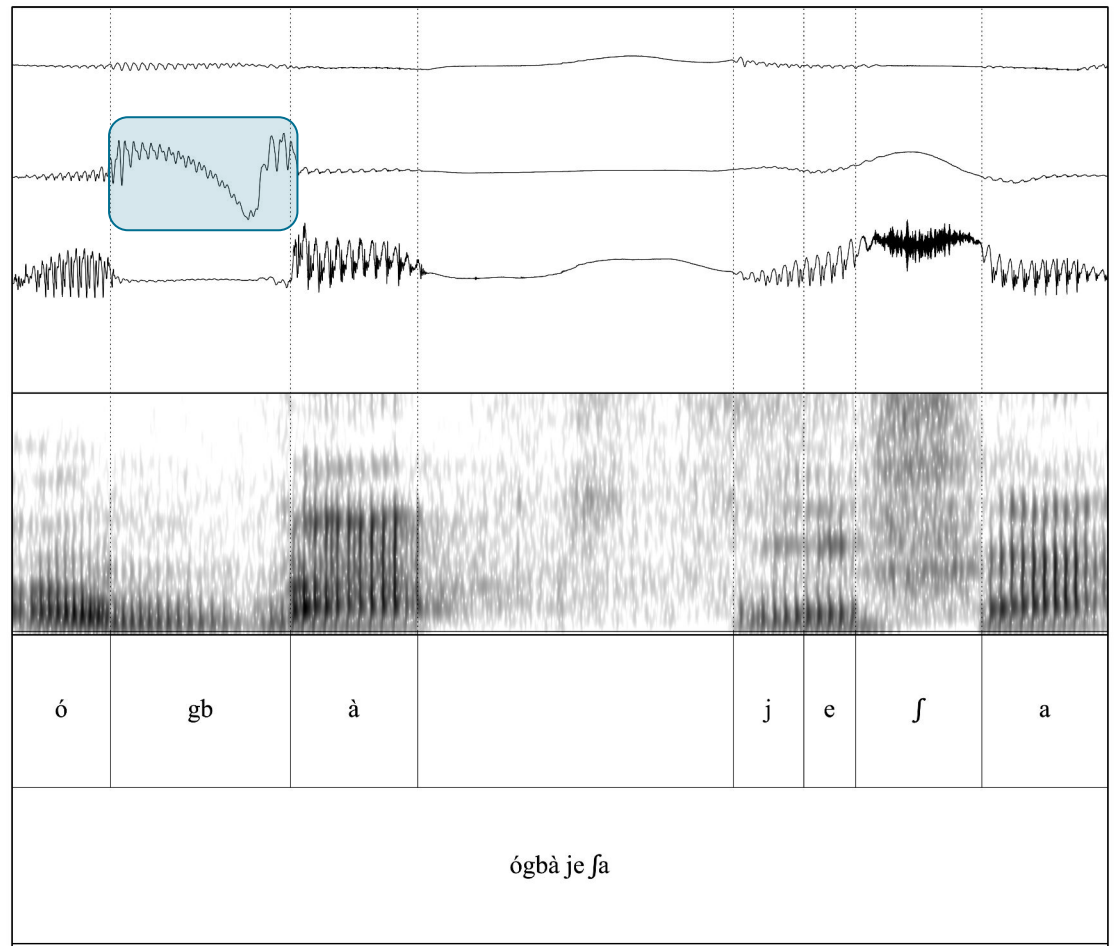
nasal flow
oral pressure
oral flow



nasal flow
oral pressure
oral flow



nasal flow
oral pressure
oral flow



739.9

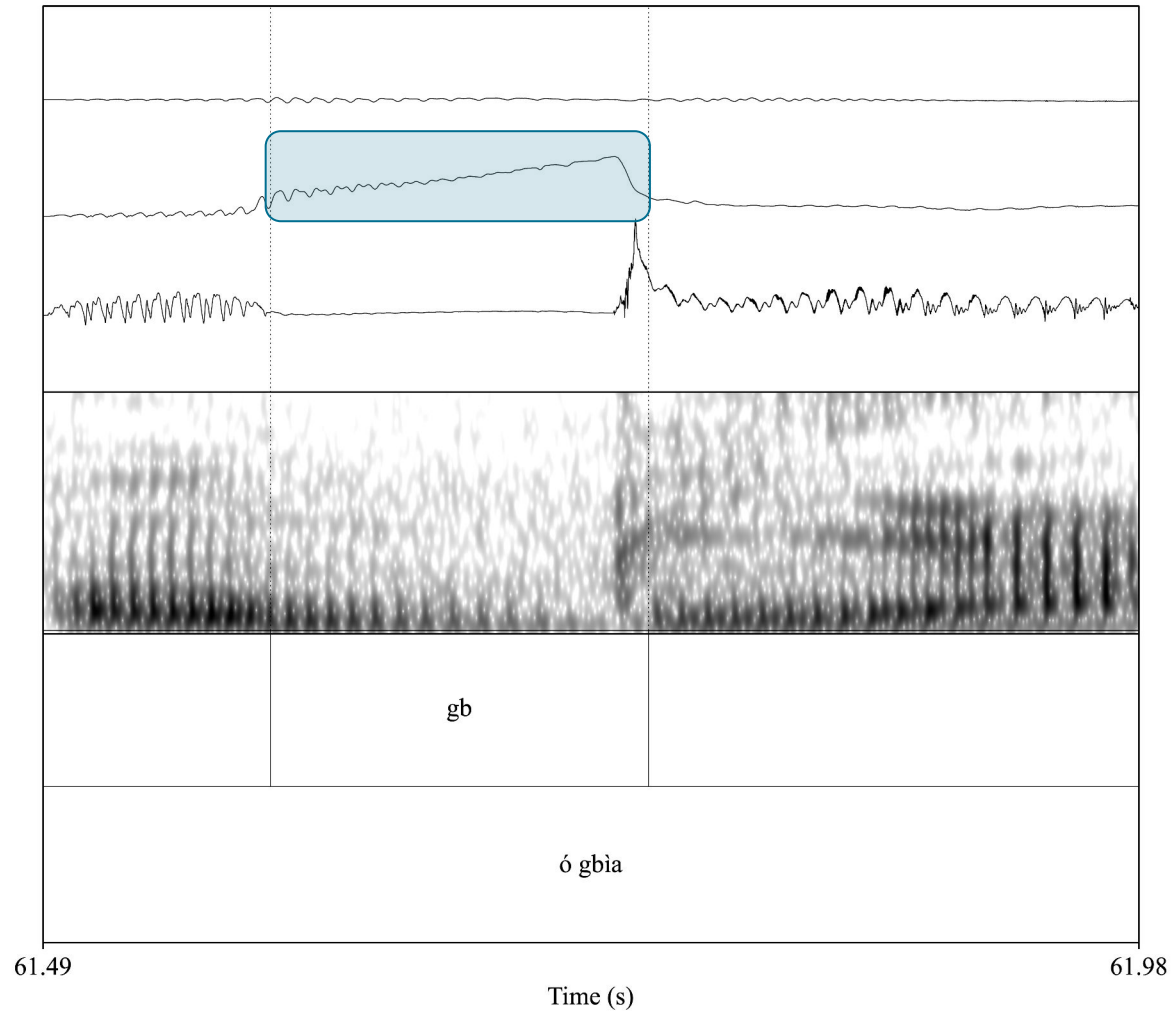
Time (s)

741

nasal flow

oral pressure

oral flow



Results

- Acoustically, implosives in Nghlwa are distinguished from plosives through longer durations and higher, steadier intensity contours
- /b₁/ (*b) and /b₂/ (*p) are incompletely neutralized in the acoustics
 - Though statistical testing is needed
- Bilabial implosives do not overall show rarefaction, but they show a steady maintenance of oral air pressure or slight increase
 - It remains to be seen if the rest of the implosive inventory also has rarefaction
- Non-implosive labiovelar /gb/ is sometimes produced with rarefaction

Implications

- Implosives can look aerodynamically different from each other within a language
 - But still share the same acoustic cues
- Differences in phonetic cues , both between consonants and within a single consonant, can also explain patterns in the phonology
 - why /b/ patterns with both obstruents and sonorants (no rarefaction)
 - but other implosives pattern with obstruents (possible rarefaction?)

Next steps

With the current data...

- Quantifying aerodynamic data, examining amount of oral pressure and pressure change
- Analyzing the EGG signal

In the future...

- Aerodynamic measurements for other places of articulation

Thank you!

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