The acoustic properties of implosives in Guébie (Kru)

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Acknowledgements

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- Thanks also to research assistant Katherine Russell.
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Introduction

Introduction

- **Phonological puzzle:** In Guébie, a Kru language spoken in Côte d'Ivoire, the bilabial implosive /ɓ/ patterns phonologically with sonorants and not with obstruents.
  - This is not predicted by most feature theories, which assume that implosives are obstruents (plus some laryngeal feature).
- **In this talk:**
  - We provide background on the phonology of Guébie,
  - And we present an acoustic study designed to investigate whether the phonetic production of Guébie /ɓ/ is more similar to that of sonorants than obstruents along any dimension.
  - **Goal:** Can we identify any phonetic dimension (feature) that implosives share with sonorants, to the exclusion of obstruents, which might be leveraged in phonological accounts?

Overview

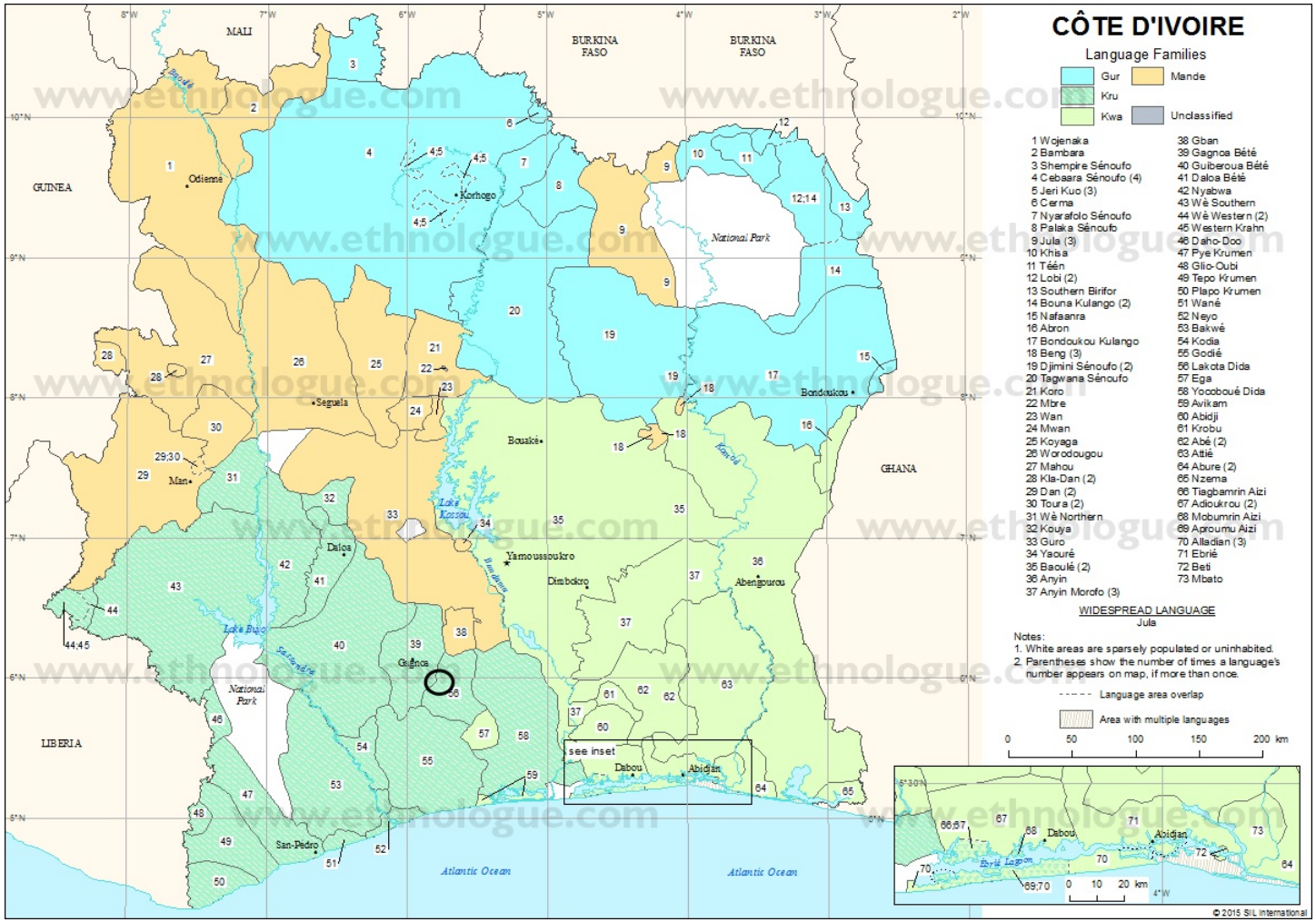
The Guébie language

Language background

Guébie (also sometimes written Guébié or Gaɓogbo) is an Eastern Kru language spoken in southwest Côte d'Ivoire.

- The data presented here comes from five speakers in Gnagbodougnoa, Côte d'Ivoire.
- The phonological generalizations are based on data collected between 2013-2024.
- The data for the acoustic study were collected in 2019.
- Data is available in the California Language Archive (Bodji and Sande, 2024).

Languages of Côte d'Ivoire



Phonological overview

Typological properties of Kru languages

Kru languages are spoken in Liberia and Côte d'Ivoire and tend to have the following phonological traits (Marchese (1979) among others):

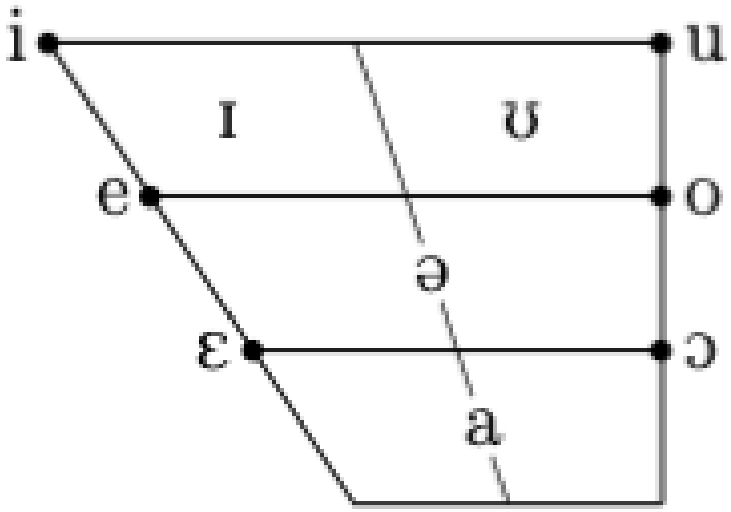
- 4 contrastive tone heights, plus contour tones
- Grammatical tone
- Primarily CV words
- Large vowel inventories (relative to other sub-Saharan African languages)

Consonant inventory

	Bilabial	Lab. dent.	Alveo-palatal	Palatal	Velar	Labialized	Labio-velar
Plosive	p b		t d	c ɟ	k g	k^w g^w	kp gb
Nasal	m		n	ɲ	ŋ	$ŋ^w$	ŋm
Fricative		f (v)	s (z)				
Approx	ɓ		l	j			w

- /v/ and /ŋm/ are rare
- /z/ is only used in proper names, ideophones, and, for some speakers, loans
- Like many Sub-Saharan African languages, Guébie has contrastive labiovelars /kp, gb, ŋm/ (Clements and Rialland, 2008)
- Also like many Sub-Saharan African languages, Guébie has a contrastive implosive /ɓ/ (Clements and Rialland, 2008)

Vowel inventory



- The +High, -ATR vowels /ɪ,ʊ/ are less frequent than other vowels
- +ATR vowels: /i, e, u, o, ə/
- -ATR vowels: /ɪ, ɛ, ʊ, ɔ, a/
- No contrastive nasal or long vowels, though both can appear on the surface in derived contexts

Segmental alternations

Regular segmental alternations include the following (Sande, 2017, 2022):

- ATR harmony
- Nasal harmony
- /l/ → [r] in C2 position: C**C**V
- Vowel replacement
- Reduplication
- Hiatus resolution (via glide insertion or vowel deletion, depending on the vowels and morphosyntactic context)

Syllable structure

Syllables in Guébie can be /V/ or /CV/.

- CVN syllables are possible on the surface when an utterance-final vowel deletes.
- **CCV syllables are possible on the surface when C2 is /l, j, w, ɓ/** (Sande, 2017, Ch. 5).

Table: CVCV → CCV

	CVCV	CCV	Translation
a.	jɪla$^{2.3}$	jla^{23}	'ask'
b.	bala$^{3.3}$	bla^{3}	'hit'
c.	duɓu$^{3.3}$	dɓu^{3}	'mourn'
d.	ɓili^{31}	ɓli^{31}	'fall'
e.	kpala$^{3.3}$	kpla^{3}	'be.sharp'
f.	bete$^{3.1}$	*bte^{31}	'break'

Nasal-oral sonorant co-occurrence restrictions

Implosives and oral sonorants (L) do not appear after nasals (N) in monomorphemic words, while obstruents (T) co-occur freely with nasals, implosives, and oral sonorants.

- TVTV, LVLV, LVTV, TVLV, NVTV, TVNV, *NVLV
- In a corpus of nearly 4,000 distinct words, sonorants [j, w, ɓ, l] appear very infrequently as the C2 after a nasal C1.
  - Only 38/540 nasal-C1 words have an oral sonorant C2, and these are all loans and proper nouns.
- Outside of proper names and loans, sonorants and /ɓ/ systematically fail to surface after nasals.

Nasal harmony

Suffixes that begin with /l/ have an [n]-initial form after roots whose final consonant is nasal.

(1) **Nasal harmony in reciprocal and applicative**

	Reciprocal	**Applicative**	**Gloss**
a.	li^{3}-li^{2}-li^{2}	li^{3}-li^{2}	'eat'
b.	gbala$^{2.4}$-gbala$^{2.2}$-lɪ^{2}	gbala$^{2.4}$-lɪ^{2}	'climb'
c.	pi^{3}-pi^{2}-li^{2}	pi^{3}-li^{2}	'cook'
d.	ni^{4}-ni^{2}-ni^{2}	ni^{4}-ni^{2}	'see'
e.	ɲɛ^{42}-ɲɛ^{2}-nɪ^{2}	ɲɛ^{42}-nɪ^{2}	'give'
f.	ɲɛpɛ-ɲɛpɛ-lɪ$^{3.1.2.2.2}$	ɲɛpɛ-lɪ$^{3.1.2}$	'sweep'

- There are no suffixes containing /ɓ/ in Guébie, so we cannot see a synchronic alternation.

Phonological behavior of /ɓ/ across Kru

As in Guébie, implosives across Kru languages pattern with sonorants to the exclusion of obstruents (Kaye et al., 1981).

- In Vata, tone spreading rules apply to implosives in the same way as sonorants.
- Tones spread onto following low-toned words that begin with a sonorant or implosive.
- Obstruents block tone spreading while implosives and sonorants do not.

Table: Tone spreading in Vata, (Kaye et al., 1981, 80)

	Underlying	*Surface*	*Gloss*
a.	n^3 li^1	n^3 li^3	'I ate'
b.	n^3 ɓuɓie$^{1.1.2}$	n^3 ɓuɓie$^{31.1.2}$	'I pardoned'
c.	n^3 bada$^{1.1}$	n^3 bada$^{1.1}$	'I hung'

Phonological behavior of /ɓ/ across Kru

As in Guébie, laterals and implosives across Kru fail to co-occur with nasals.

- Some Kru languages are analyzed as not having contrastive nasal consonants.
- Instead, surface nasal Cs are derived from underlying sonorants and implosives in words that contain nasal vowels.

Phonological behavior of /ɓ/ in Guébie

In nasalization and consonant clusters, implosives pattern with sonorants to the exclusion of obstruents.

- This behavior is surprising given that most feature theories consider implosives to be obstruents (plus an extra laryngeal feature), though see Sande and Oakley (2023).
- In a perception study, Guébie listeners found implosives more similar to obstruents than sonorants (Oakley and Sande, 2023).
- Here we ask whether any acoustic feature of implosives is more similar to that of sonorants than obstruents.

Acoustic study

How do implosives, obstruents, and sonorants differ acoustically?

Is the phonological patterning of implosives as sonorants based in any phonetic similarity?

- Because air pressure decreases over time due to the lowering of the larynx
  - It has been found for Chinese languages (Cun, 2009) that intensity slope increases over time for implosives, but decreases over time for obstruents (see Coburn and Hjortnaes (2019) for an acoustic study of implosives and obstruents in Swahili)
- Languages differ in the articulatory properties of implosives
- One proposal: implosives are characterized by a lack of air-pressure build up in the oral cavity (Clements and Osu, 2002)

Methods

This study: compare the phonetic (acoustic) properties of implosives, sonorants, and obstruents to see whether their phonological patterning is based on phonetic similarities

- Participants
  - 5 Guébie speakers (2 male, 3 female, age 20-40)
- Production task
  - 30 minute elicitation tasks in quiet setting in a Gnagbodougnoa, Côte d'Ivoire
  - Recorded using an H4n recorder and levalier microphone
  - Translation task: translated French phrases into Guébie, and repeated 3 times
  - Selected one phrase for analysis per repetition
  - Phrases were designed to combine each consonant with a variety of vowel qualities and tone heights
  - Only included consonants in inter-vocalic position in the current analysis

Methods: Tokens

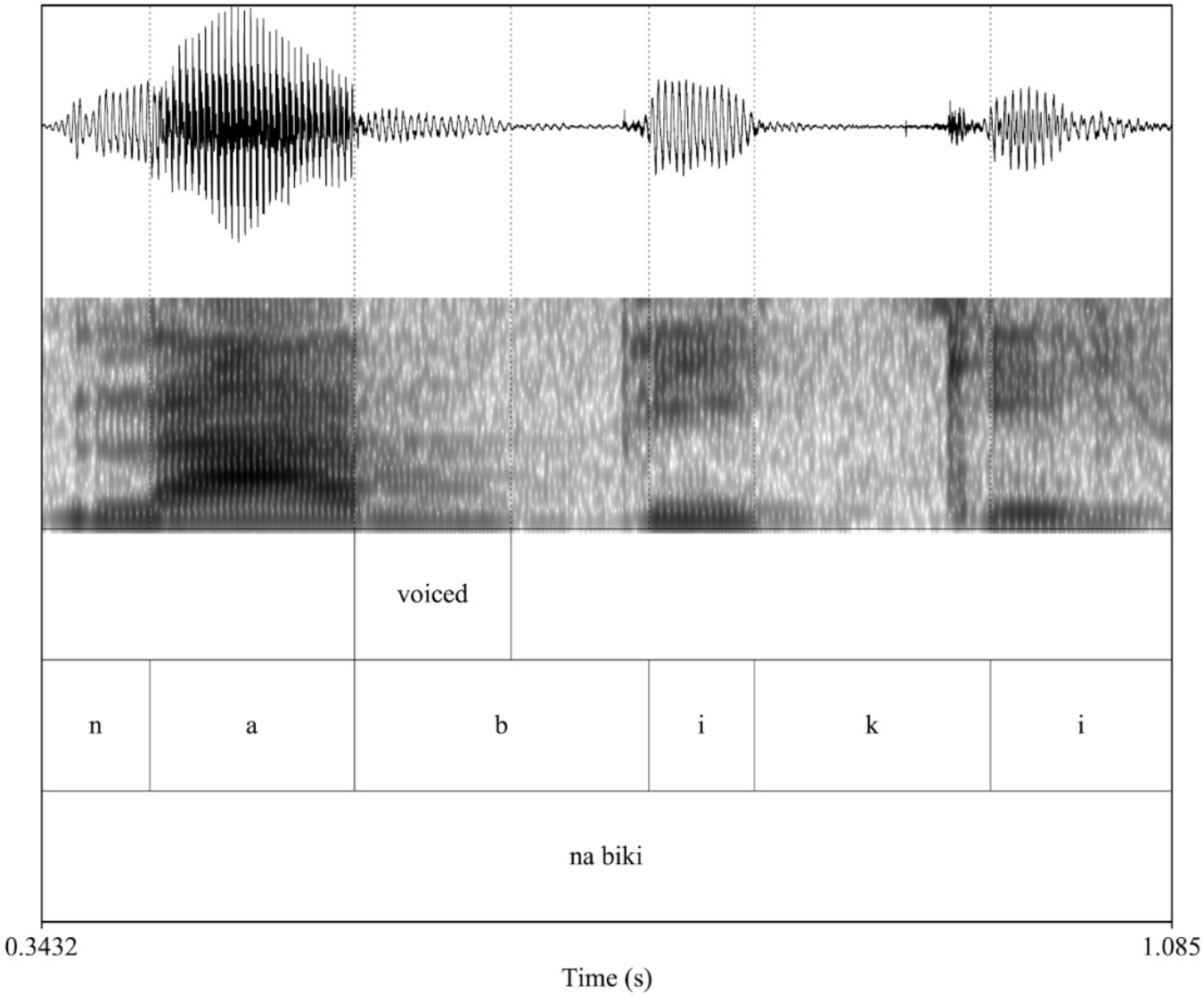
Table: Tokens produced by speaker

	S1 (M)	S2 (M)	S3 (F)	S4 (F)	S5 (F)
Voiced obstruents	238	203	146	38	40
Sonorants	709	518	471	166	130
Implosives	227	159	106	99	65

Methods: Analysis

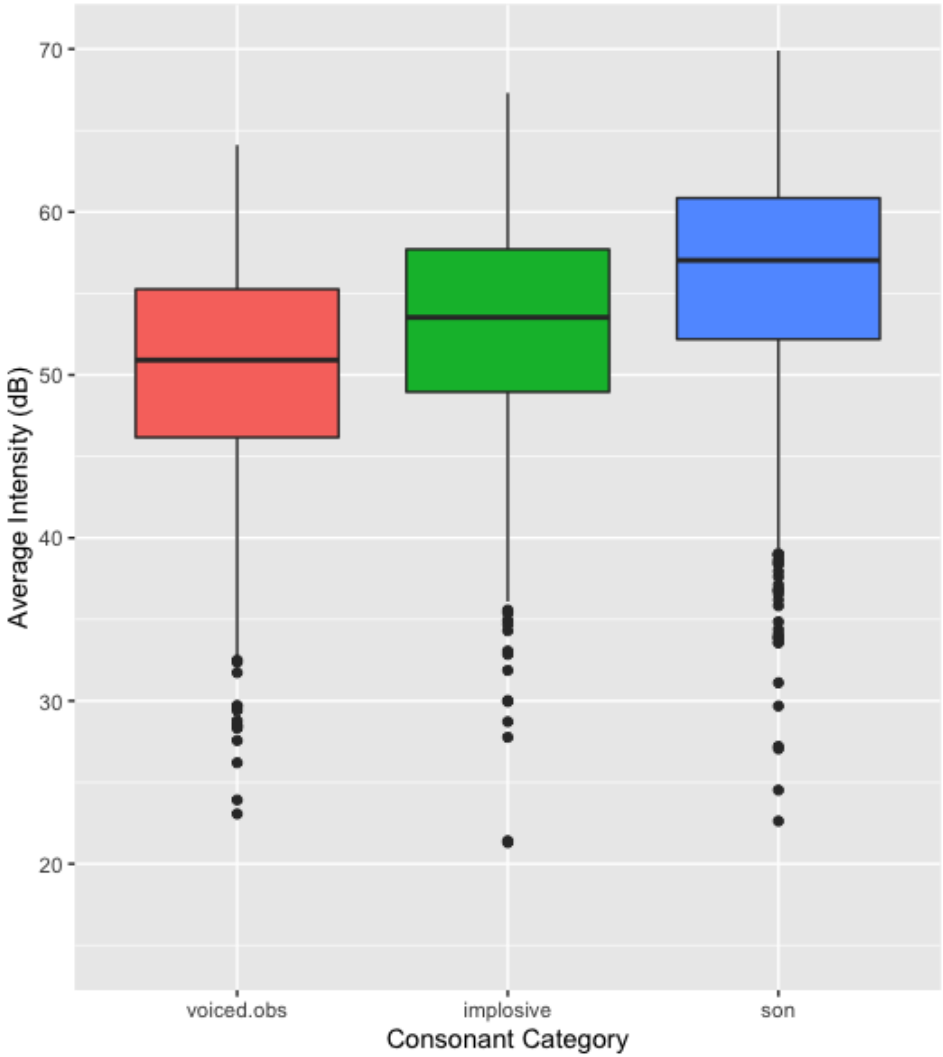
- Elicitation sessions were transcribed in Praat by hand and manually corrected by a second researcher
- Target consonants measured for:
  - Average intensity (dB)
  - Intensity slope (measured at 75% - 25% of consonant/(consonant duration*.5))
  - Voicing duration (ratio of voiced portion of consonant over the total duration of the consonant)

Methods: Sample textgrid



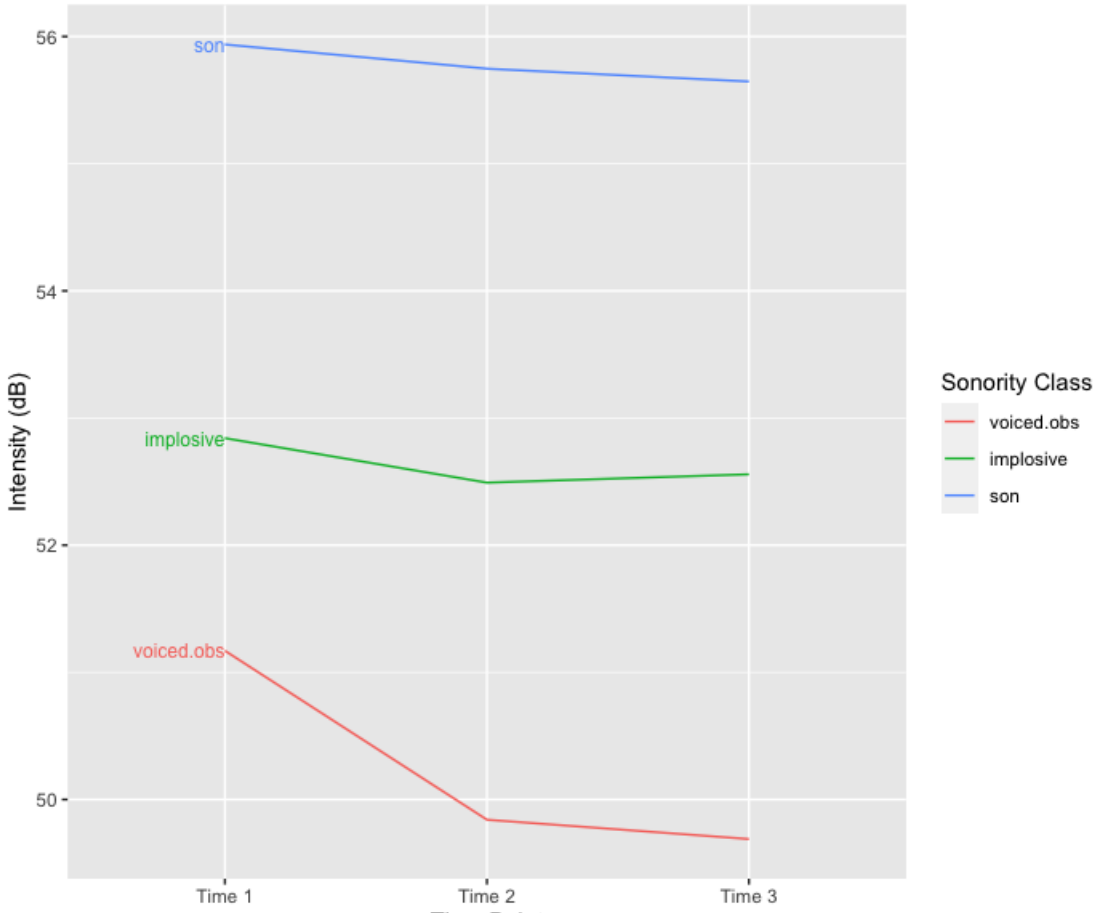
Results: Average intensity

Average intensity: ANOVA implosives, voiced obstruents, and sonorants all differ in average intensity ($F=223.6$, $p < .001$)



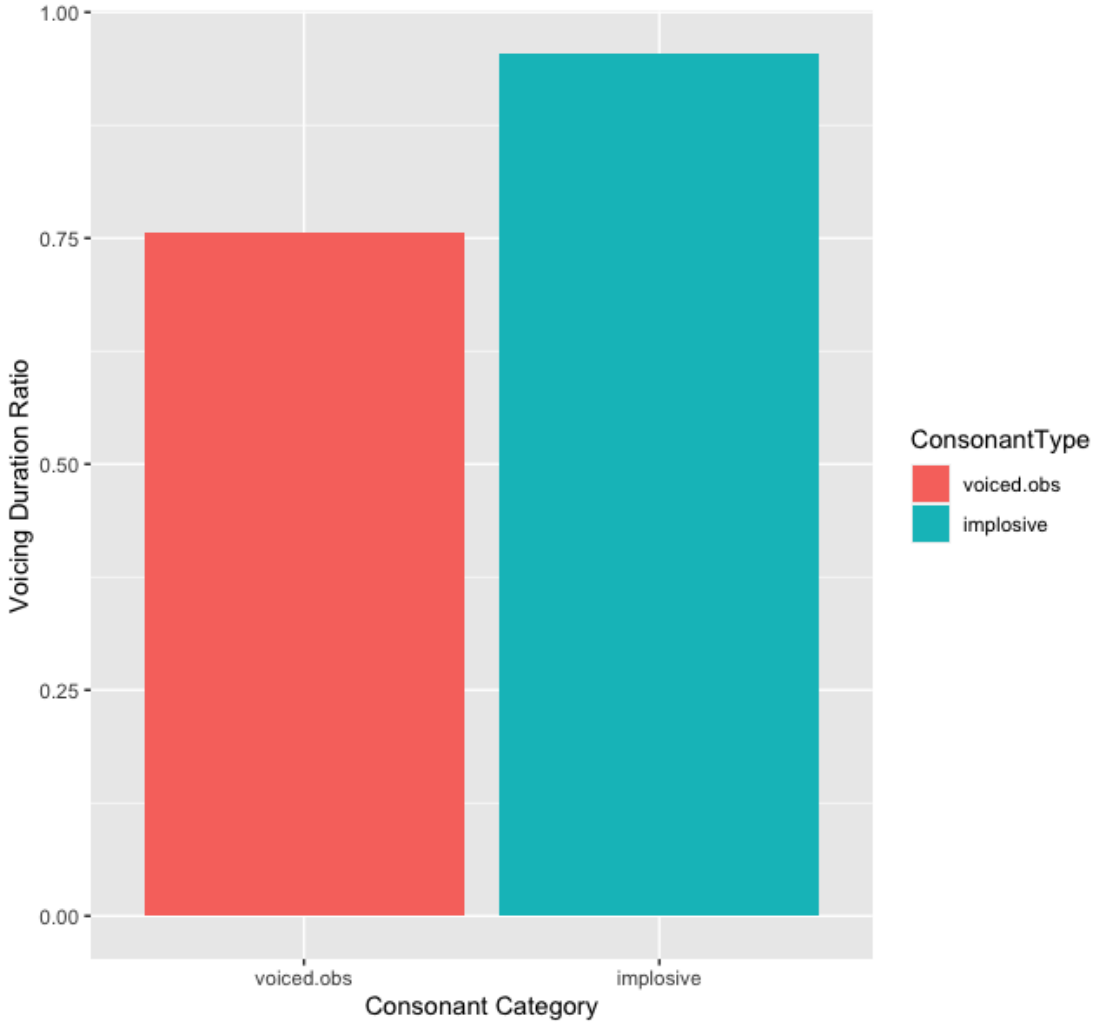
Results: Intensity slope

Intensity Slope: ANOVA shows significant difference between consonant types ($F=14.51$, $p < .001$). Tukey HSD shows implosives and sonorants differ from voiced obstruents, but not from each other ($p=.93$)



Results: Duration

Voicing Duration Ratio: t-test shows significant difference between consonant types (t=170.6, p <.001).



Discussion and conclusion

Discussion

Recall that phonologically, /ɓ/ patterns with sonorants to the exclusion of obstruents in Guébie.

Phonetically:

- Perceptually, Guébie listeners perceive /ɓ/ as more similar to obstruents than sonorants (Oakley and Sande, 2023).
- Implosives pattern differently from sonorants and voiced obstruents in average intensity
- Implosives pattern similarly to sonorants in intensity slope, but differently from voiced obstruents
- Implosives and voiced obstruents differ in voicing duration

Discussion

We are left wondering what feature picks out the set of sounds that pattern together in Guébie: /ɓ, l, j, w/

- Are implosives characterized by a lack of air-pressure build up in the oral cavity, as proposed by Clements and Osu (2002)?
  - Results from Guébie do not show an increase in intensity slope, which is expected if air pressure decreases over time (as found by Cun (2009))
  - Proposal that there is a lack of air pressure build up is consistent with results here, and perhaps is an acoustic correlate to the class of 'sonorants' in Guébie

Implications

- Sande and Oakley (2023) found that in 38% of languages with implosives, they pattern with sonorants. In another 32% of languages with implosives, they show mixed patterning.
- The findings presented here suggest that the patterning of implosives with obstruents vs sonorants may be predicted by their language-specific acoustic properties.

Thanks! Ayoka!

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Appendix

Average intensity by speaker

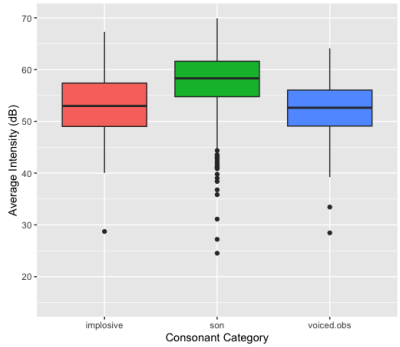


Figure: Speaker 1

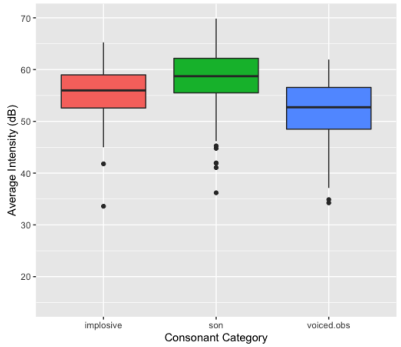


Figure: Speaker 2

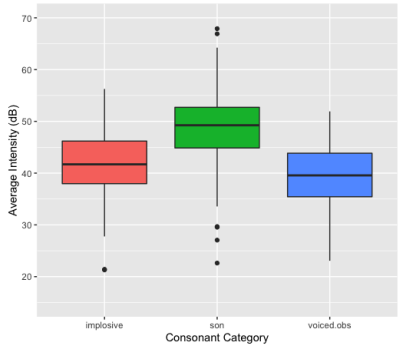


Figure: Speaker 3

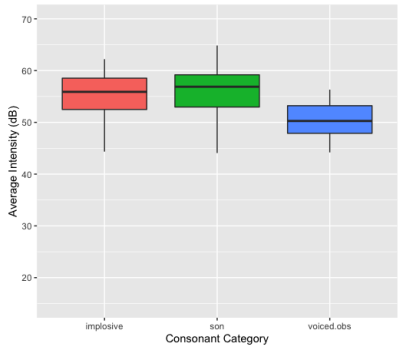


Figure: Speaker 4

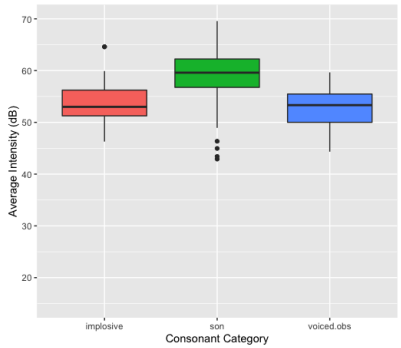
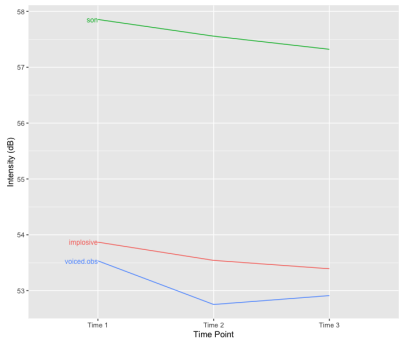


Figure: Speaker 5

Appendix

Average slope by speaker



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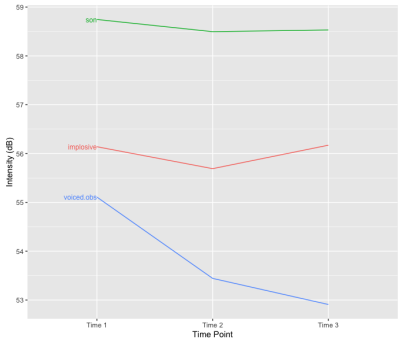
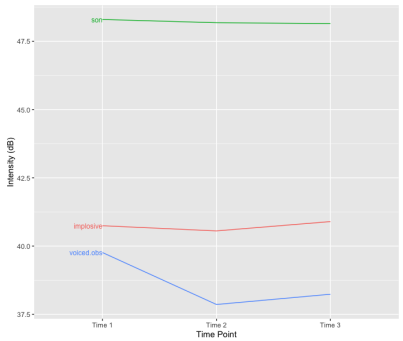


Figure: Speaker 2



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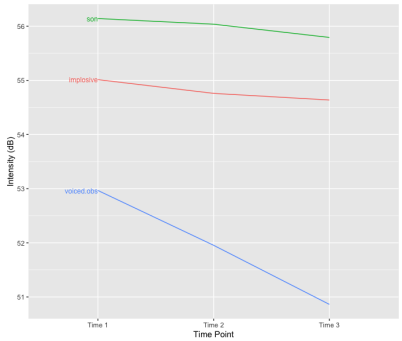


Figure: Speaker 4

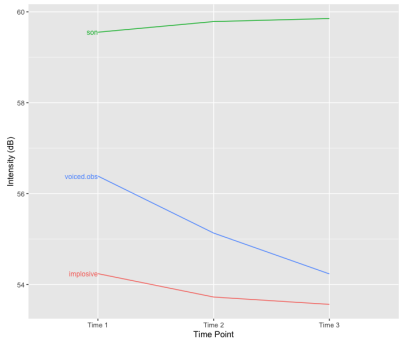


Figure: Speaker 5

Appendix

Voicing duration ratio by speaker

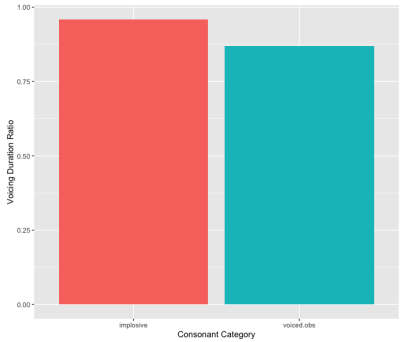


Figure: Speaker 1

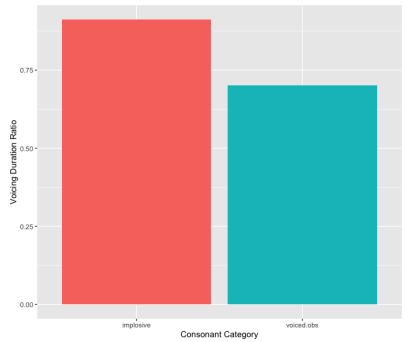
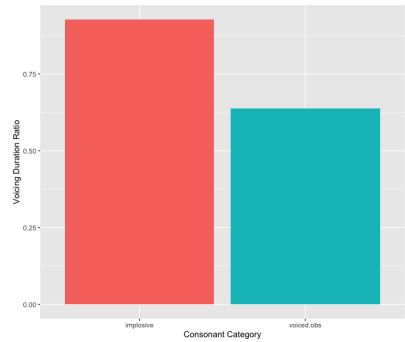


Figure: Speaker 2



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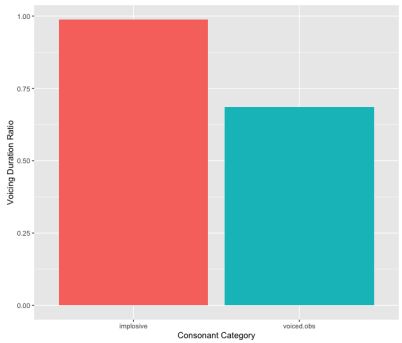

Figure: Speaker 4

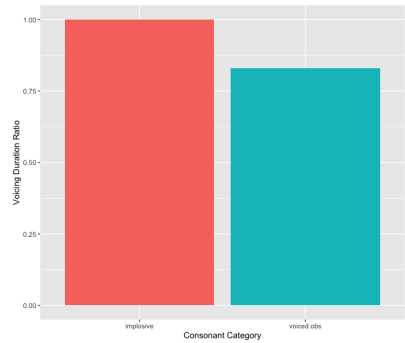

Figure: Speaker 5