Acoustic Analysis of Plosives in the Rɨkpa' Language

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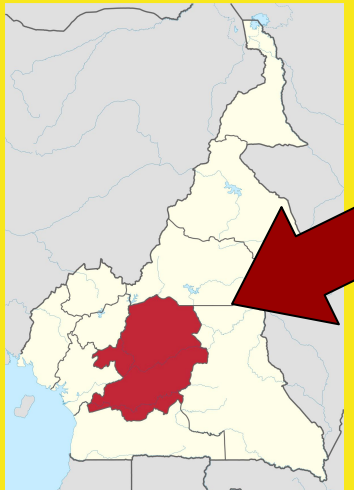
Rɨkpa Background

- **Rɨkpa'/ kpɑ̄ʔ/ Bafia**
  - Bantu language
  - Region: A.53
- **Classification:** Niger-Congo›› Atlantic-Congo›› Volta-Congo›› Benue Congo›› Bantoid›› Southern›› Narrow Bantu›› Northwest›› A›› Bafia
- **Speaking population:** approximately 25,000
- **Dialects:** Kpa, Bape, Bekpak, Ripey
- **Additional languages:** English and French

Geographical Background

- Spoken in Cameroon
- Centre Region: Mbam and Inoubou division
- Bafia, Kaliki, and Kon-Yambetta subdivisions
- North of Sanaga River
- Lefa, Yambeta, and Gunu languages surround Bafia

Cameroon



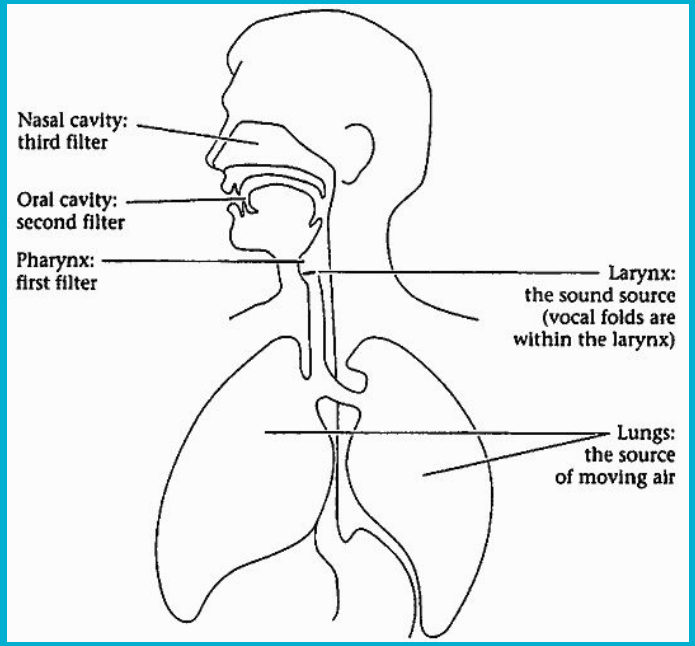
Centre Region, Cameroon

Centre Region

Republic of Cameroon

Egressive vs. Ingressive Mechanisms

- Pulmonic egressive sounds:
  - Air moves from the lungs through the larynx to create sound
  - Positive air pressure
- Glottalic ingressive sounds (**implosives**):
  - Larynx moves downward while oral cavity is closed
  - Negative air pressure buildup
  - Air moves inward through oral cavity
  - Ingressive airflow usually followed by egressive airflow to produce consonant



Rɨkpa' Consonants: Plosives and Implosives

- 25 contrastive consonants
- Two implosive consonants: **Bilabial [ɓ] and alveolar [ɗ]** (Hagege, 1975)
  - Can occur in both high and low tone environments
- Voiced and voiceless plosives: bilabial, alveolar, velar, labiovelar
- Near minimal pair examples:
  - **ɓ**àm *bag*, **b**àn *town*, **p**án *dish*
  - **ɗ**ú *fire*, **d**úŋ *mold*, **t**ú *spit*

Rikpa' Consonant IPA Chart

	Anterior		Central			Posterior	
ORAL	Bilabial	Labio-dental	Apical	Post-apical	Palatal	Velar	Labio-velar
Implosives	ɓ		ɗ				
−voice	p	f	t	s	c	k	kp
+voice	b	v	d	z	j	g	gb
Continuants	w		l	r	y	ɣ	
NASAL	m		n		ɲ	ŋ	

Implosives, Plosives, and Fundamental Frequency

Implosive Qualities:

- Ingressive to egressive airflow
  - Higher velocity of airflow
  - Higher fo
- Lowered larynx during glottalic ingressive movement
  - Lower fo
- Stiffened vocal folds
  - Higher fo

Voiced vs. Voiceless Plosives

- Egressive airflow
  - Voiced plosive prevoicing
    - Lowered larynx
      - Lower fo
  - Voiceless plosives
    - No prevoicing
      - Higher fo

(Wright & Shryock, 1993; Bradshaw, 1997)

Past Phonetic Findings

- **Fundamental Frequency (fo): SiSwati (Bantu Region S.43)**
  - fo of vowels following implosives, voiced, & voiceless plosives
  - Vowels following implosives higher than voiced, lower than voiceless
  - *(Wright & Shryock 1993)*
- **Closure Duration: Mpiemo (Bantu Region A86); Guébie (Kru)**
  - Implosive closure duration longer than voiced plosive
  - *(Nagano-Madsen & Thornell 2012; Sande & Oakley 2020)*
- **Voicing Intensity: Mpiemo & Guébie Languages**
  - Mean intensity between obstruents and sonorants; significant difference *(Sande & Oakley 2020)*
  - Implosives show increasing intensity slope during closure/prevoicing
  - Voiced plosives show decreasing intensity slope during prevoicing

Phonological Features of Implosives

- Catford's account: Implosives are in glottal obstruent class *(1939)*
- Many languages use modifications where the atmospheric pressure is zero, a little below, or not ingressive *(Ashby 1990)*
- Clements and Osu: Implosives as nonexplosive stops, absence of oral air pressure [-obstruent, -sonorant] *(2002)*
- Implosive acoustic patterns may give us insights into their phonology
    - Sonority hierarchy: Most sonorant (e.g. liquids) to least sonorant (e.g. plosives)
    - Closure duration and intensity correlate with resonance or sonority
    - *(Sande & Oakley 2020)*

Sande & Oakley (2020-2021) Findings

- **Certain phonological patterning more characteristic of obstruent vs. sonorant-like implosives**
  - Coda Syllable Position: Obstruent-like behavior
  - Prenasalization: Obstruent-like behavior
- **Languages vary in how implosives pattern**
  - Hausa: Obstruent-like
  - Guébie: Sonorant-like
  - Ikwere: Mixed *(Clements & Osu, 2002)*
- **Gradient Feature Analysis:**
  - Implosive features gradiently activated; between nasals and voiced fricatives

Unanswered Questions

- **Implosive ambiguity**
  - Variable acoustic patterning across languages in Sub-Saharan Africa
    - Potential differences in larynx lowering, glottal constriction, and vocal fold tension
  - Extends to phonological features
    - Closure duration and intensity correlate with sonority
    - Acoustic variability↠ unclear implosive features
    - Where do implosives fit on sonority hierarchy?
- **Leads to the question...**
  - How do implosives in Ɽikpa fit into the typological picture?

(Ladefoged 1968; Lindau 1984; Sande & Oakley 2020; Wright & Shryock 1993)

Research Questions...

1) How does **fundamental frequency *(fo)*** differ between Rɨkpa vowels following implosive, voiced, and voiceless egressive plosives?

2) How does **closure duration** differ between Rɨkpa implosive, voiced, and voiceless egressive plosives?

3) How does **closure intensity** differ between Rɨkpa implosive, voiced, and voiceless egressive plosives?

Methodology

Vocabulary Stimuli Methodology

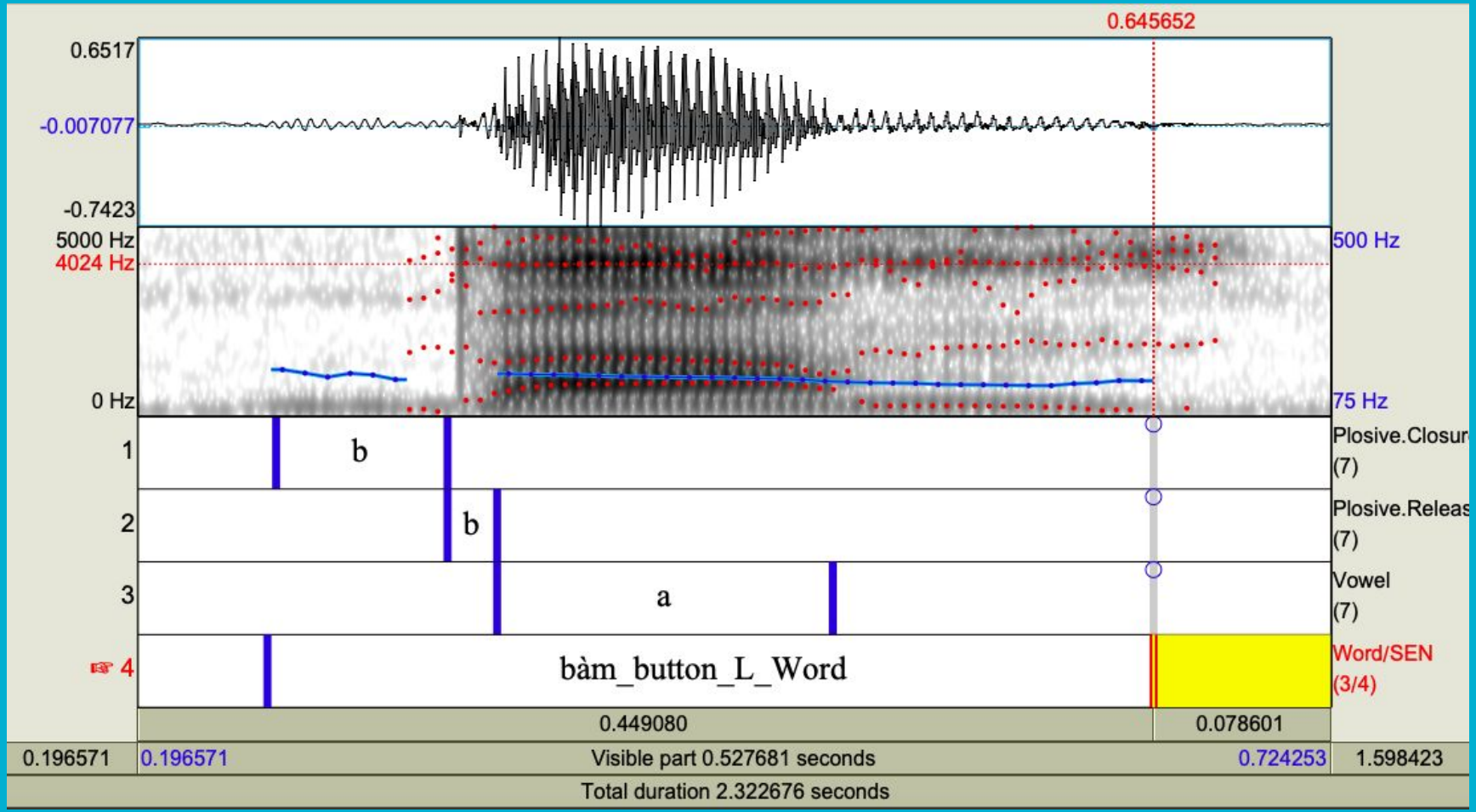
- Modified Swadesh list- Basic vocabulary often used in fieldwork
- **Consonant Criteria:** Initial and medial position
  - Implosives:[ɓ] and [ɗ]
  - Voiced plosives: [b] and [d]
  - Voiceless plosives: [p] and [t]
- **Vowel Criteria:** Variety of vowels qualities following target consonants
  - Front: [e], [i],
  - Mid: [ə], [ɛ], [ɨ]
  - Back: [u], [a], [ɔ], [o]
- **Tonal Criteria:** High and low tones for each vowel

Word-Initial Position		Word-Medial Position	
High Tone	***Low Tone***	***High Tone***	***Low Tone***
[**ɗ**ú] *Fire*	[**ɗ**ùm] *Belly*	[ʀɨ**ɗ**í] *To Eat*	[ʀɨ**ɗ**ù] *To Struggle*
[**d**úŋ] *Mold*	[**d**ùŋ] *Bush*	[ɗɨ**d**úʀɨ] Tomorrow	[ɓɨ**d**ìlà?] Food
[**t**éŋdɨ] *Mosq. Net*	[**t**ìɓí?] *Excrements*	[ʀɨ**t**é?] *To Take*	[ʀɨ**t**ùɓ] *To pour from can*
[**ɓ**óŋá] *To Wait*	[**ɓ**òRá] *Bra*	[ʀɨ**ɓ**óŋ] *To Wait*	[tɨ**ɓ**òmí] *Brain*
[**b**ú] *Dog*	[**b**ù] *Hole*	N/A	[kɨm**b**òŋ] *Prisoner*
[**p**éjɨ́] *To Pay (Imperative Form)*	[**p**ɨɣá] *To Launch (Imperative Form)*	[ʀɨ**p**é] *To Pay (Infinitive Form)*	[ʀɨ**p**ɨ] *To Launch (Infinitive Form)*

Methodology Continued

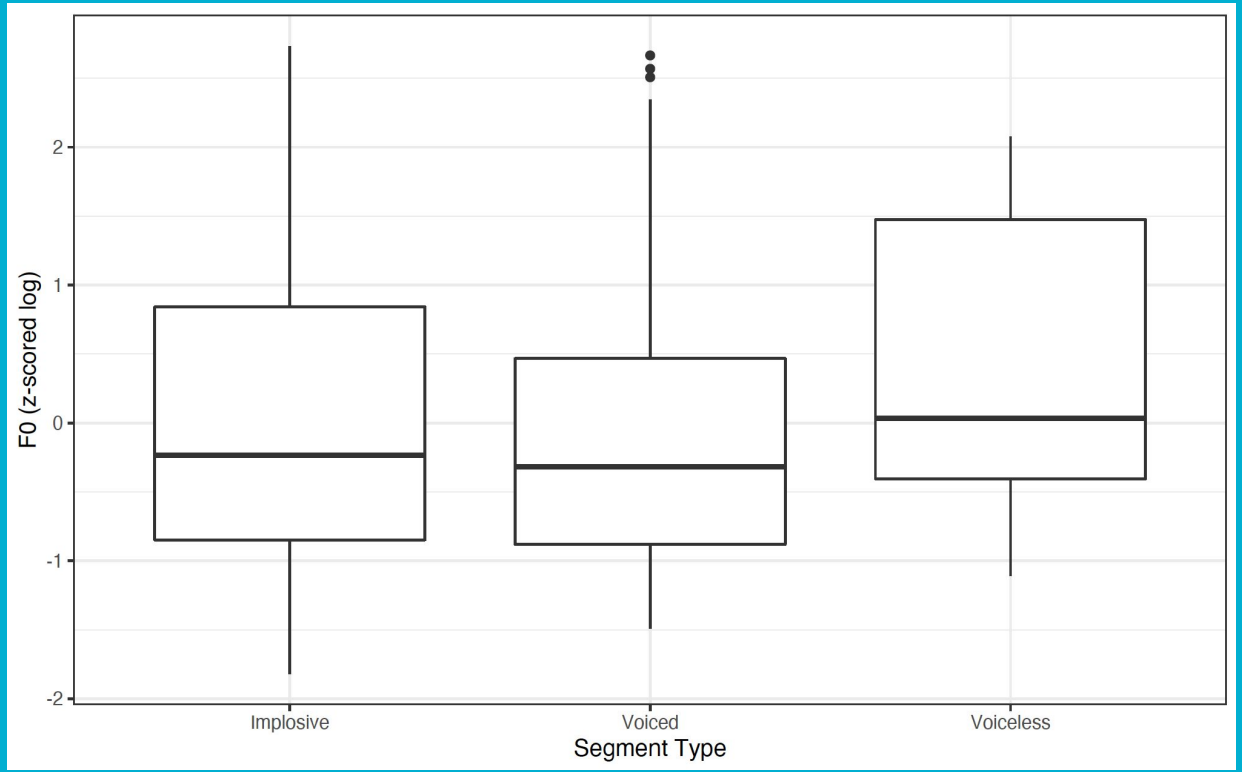
- Zoom elicitation sessions (1.5-2 hours) with Fridah
- Three female native Rikpa speakers recorded stimuli via Praat
- Three repetitions in isolation, three in sentence context per word
  - Ex: “kɨ̀dén, kɨ̀dén, kɨ̀dén” “mə̀ ă ɣɛ́ kɨ̀dén kɨ̀ dʒè á fjè”
  - English translation: “Meat, meat, meat” “I saw a piece of meat at the market”
  - Combined data for analysis
- Segmented and annotated stimuli in Praat (4 categories)
  - Plosive Closure, Plosive Release, Vowel, Word/ Sentence Context
- Ran Praat scripts for fo, closure duration, and closure intensity

Praat Annotation Example…



Results

Overall Effects of Segment Type on F0



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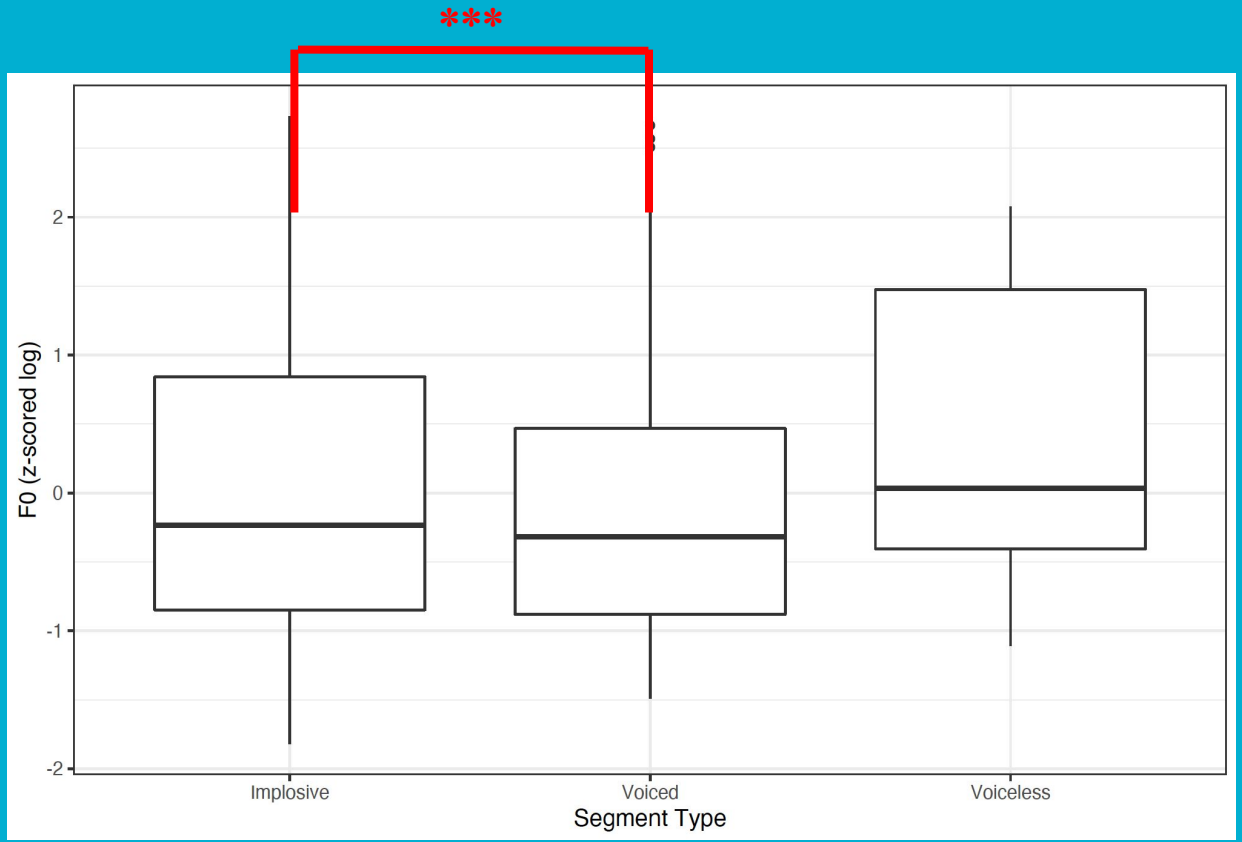

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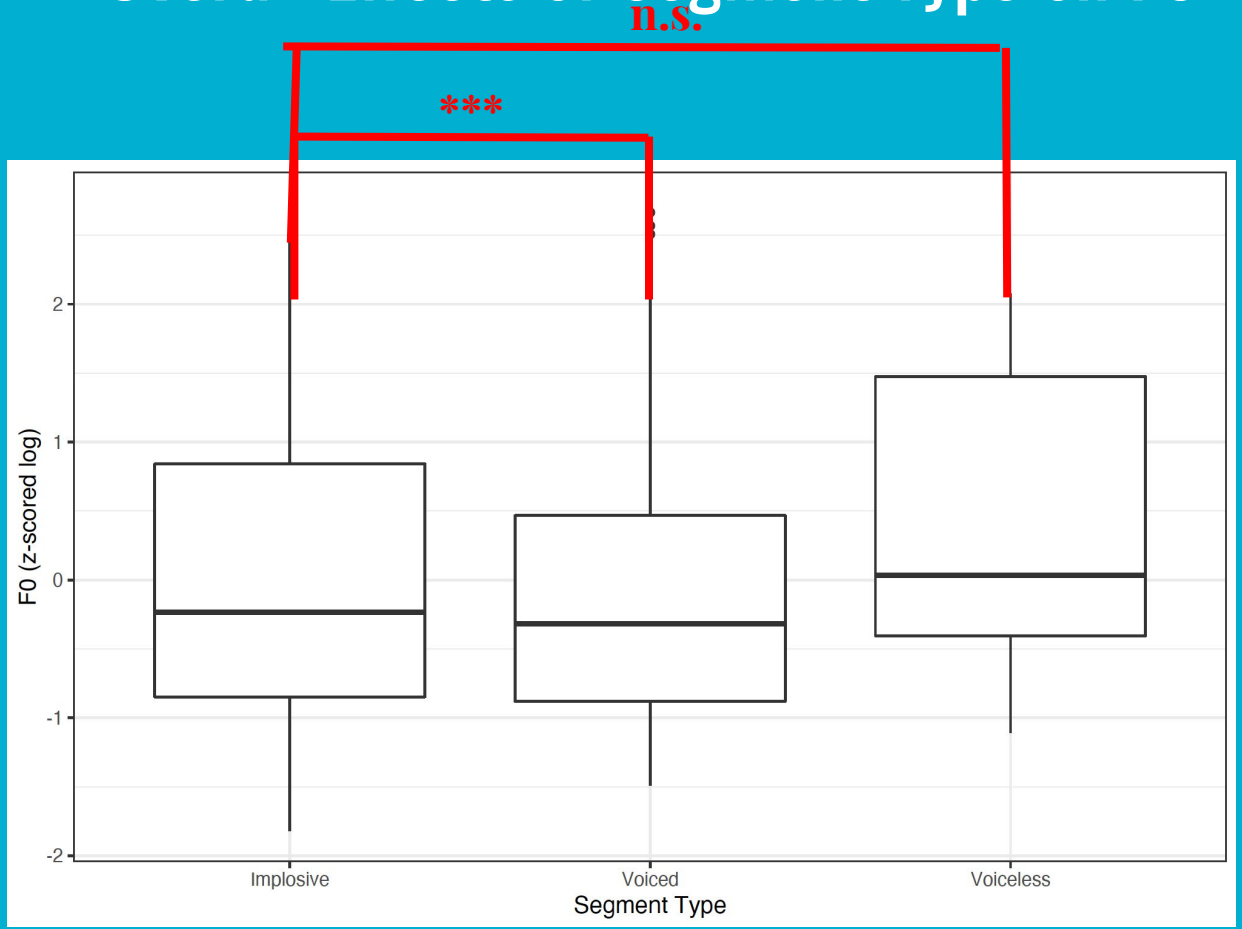
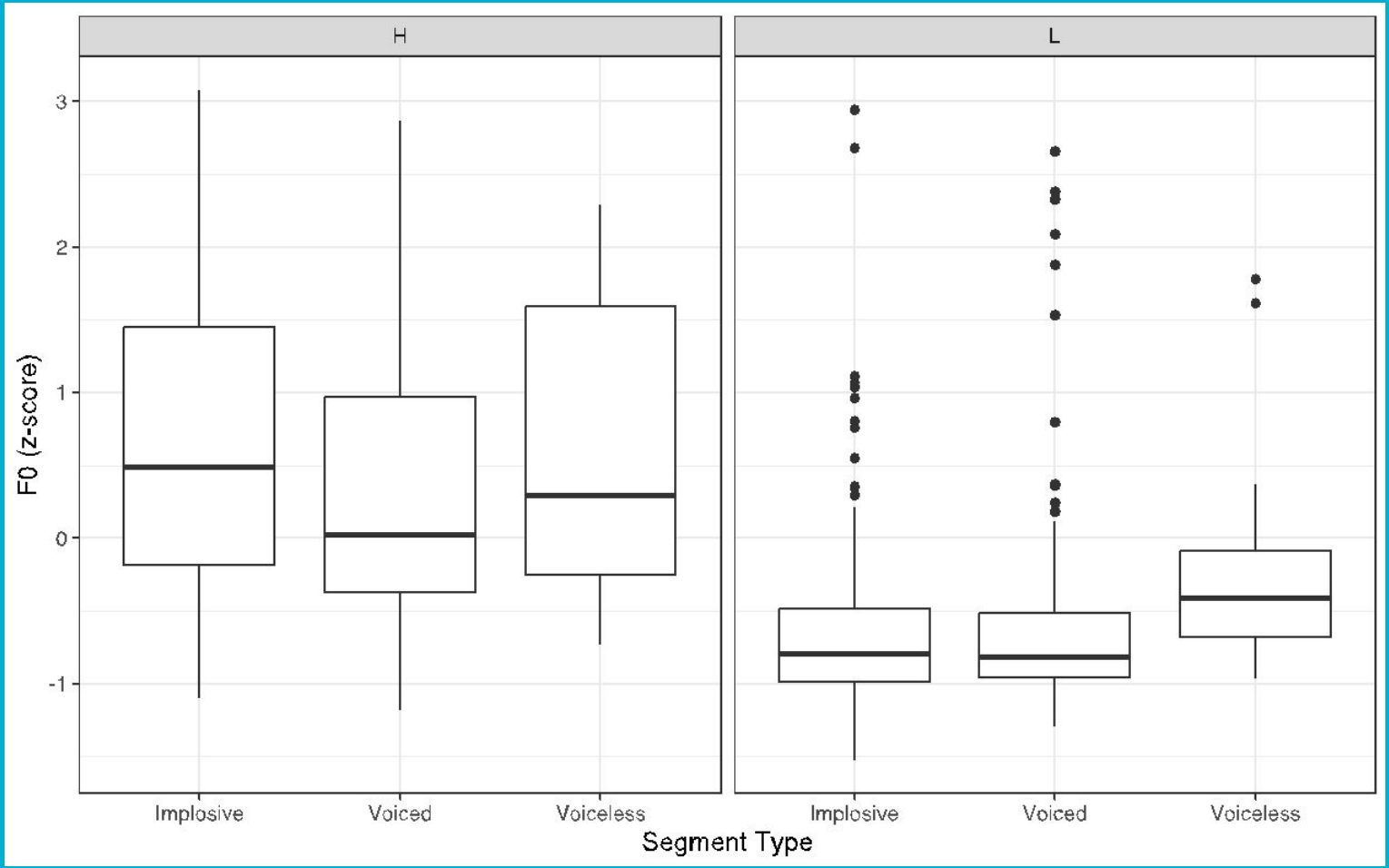


Segment Type and Tone on F0



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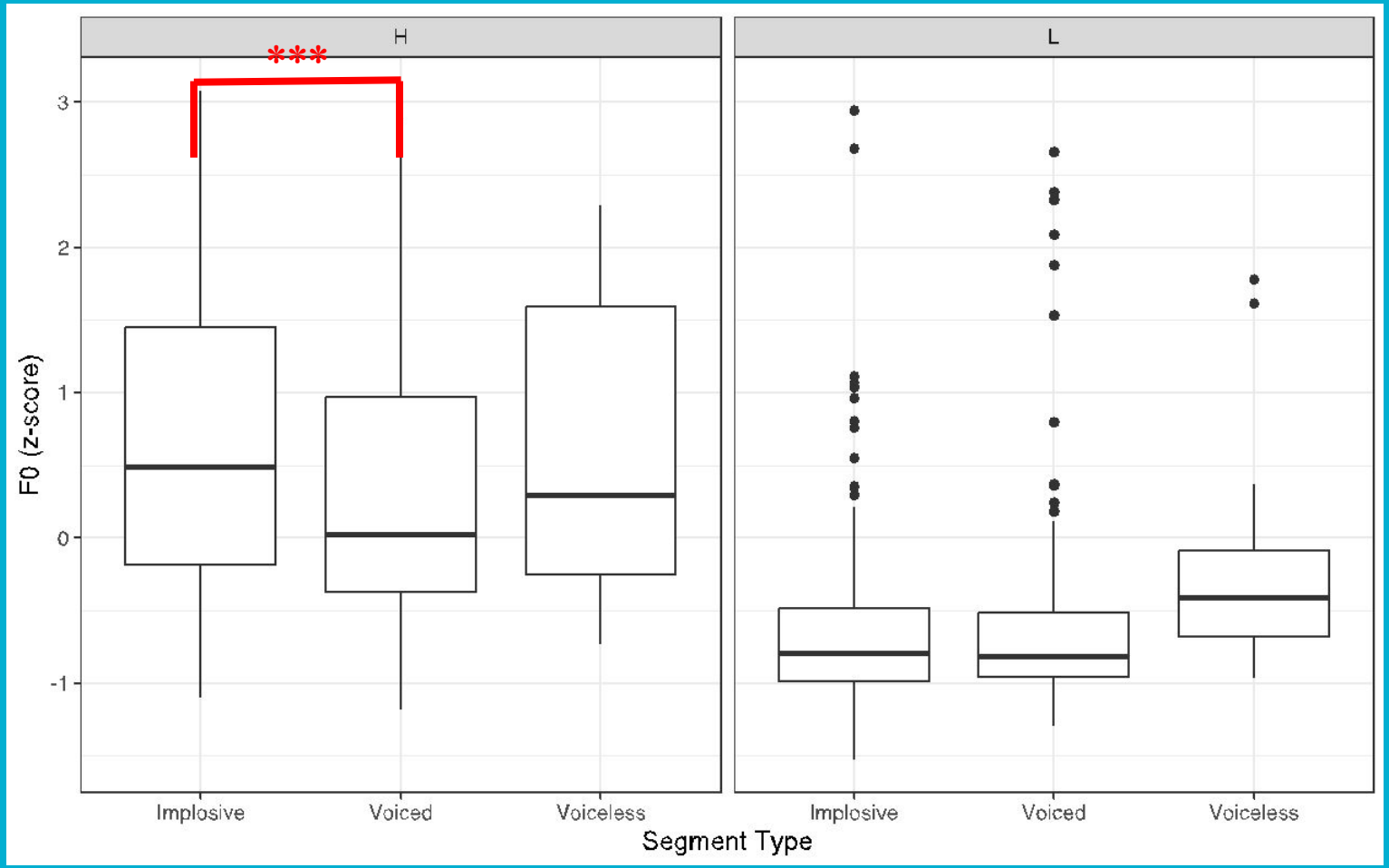

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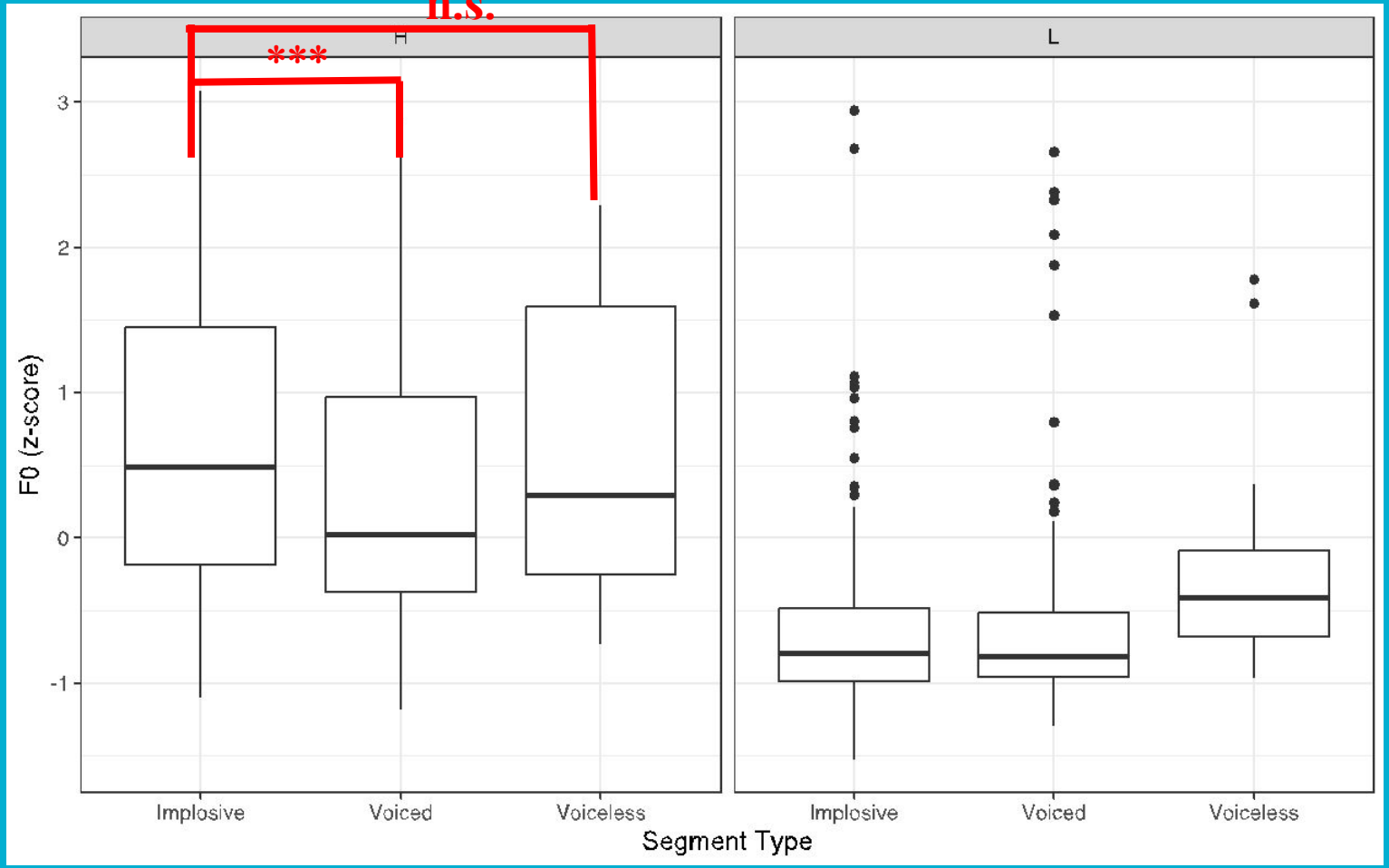

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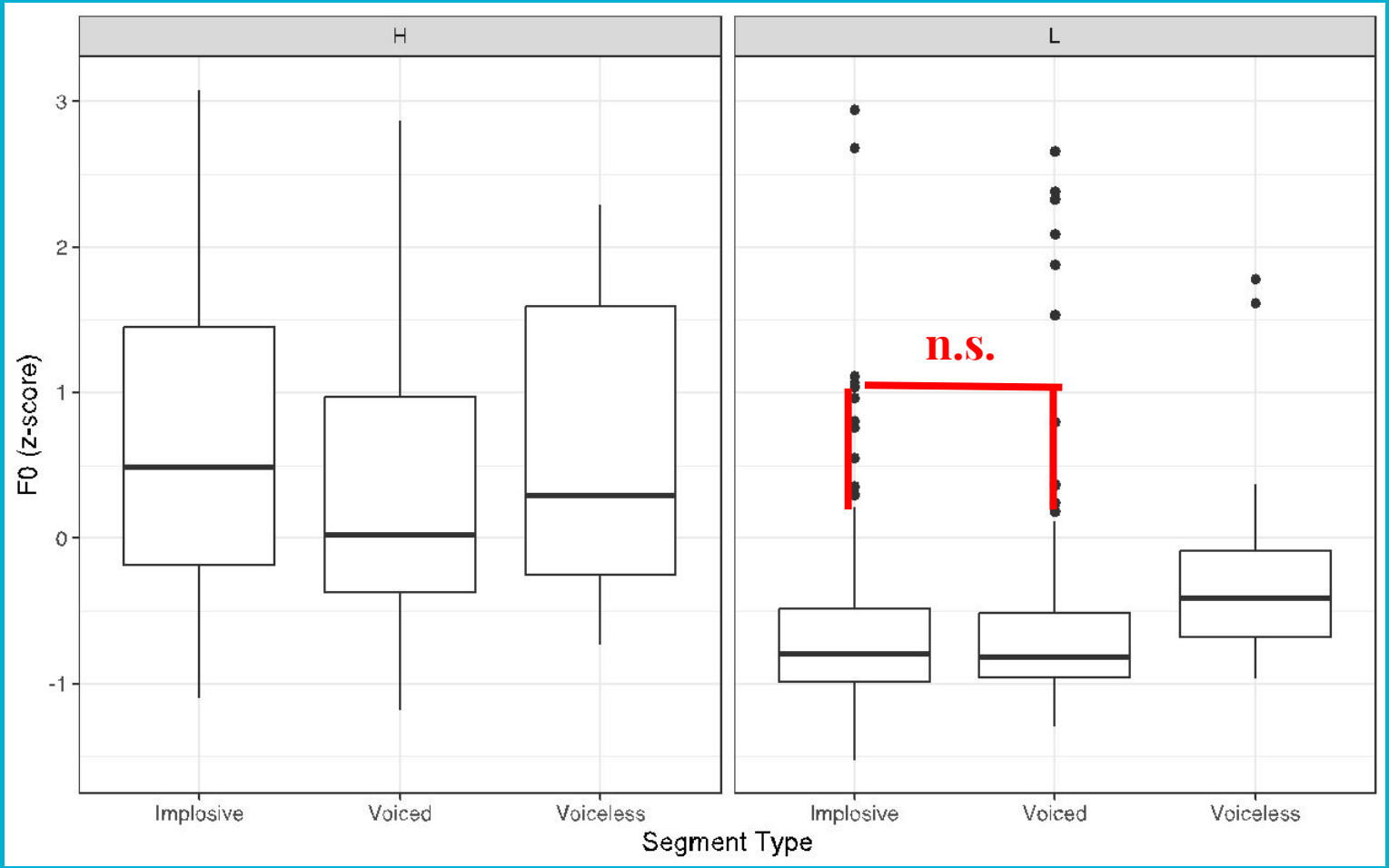

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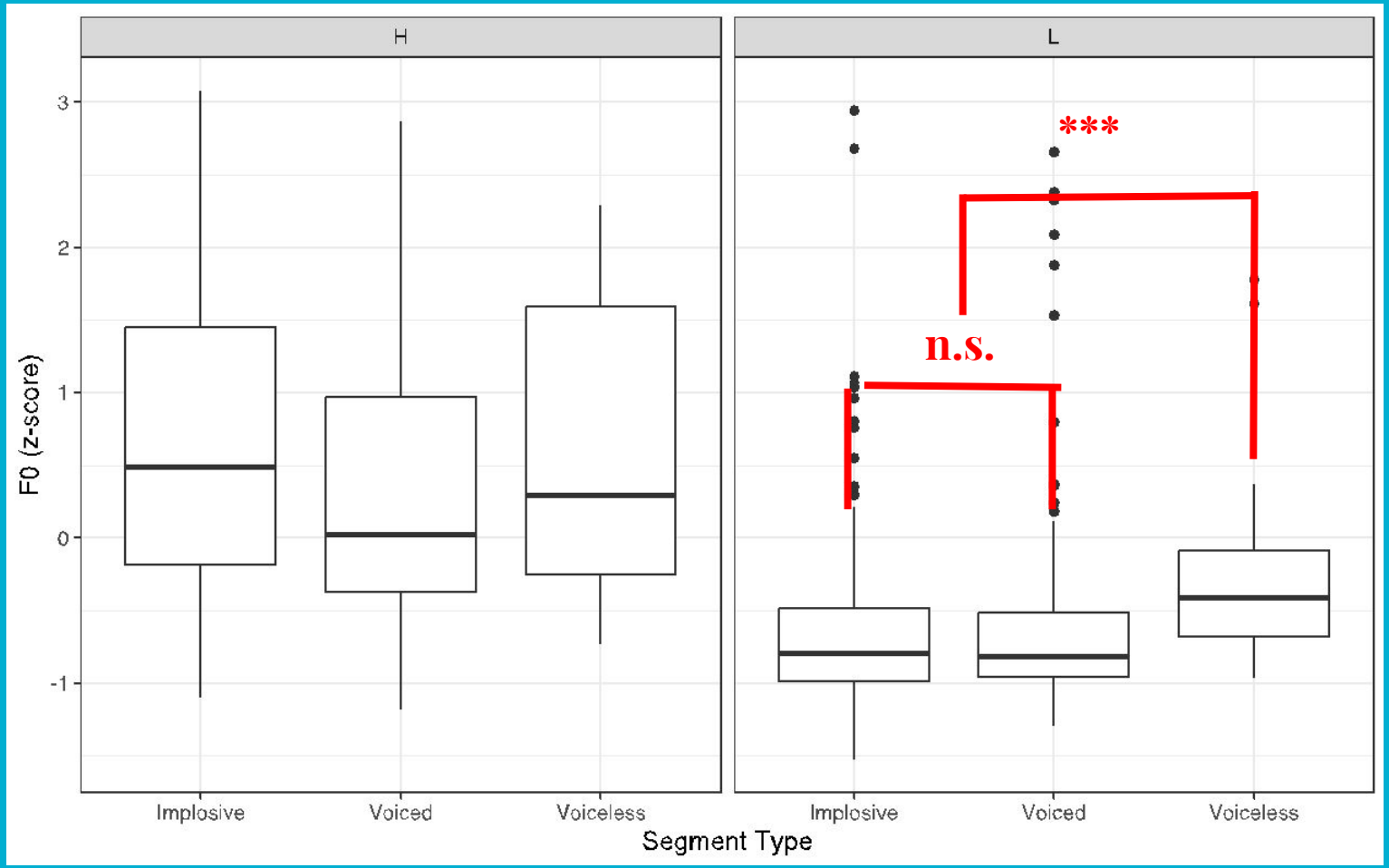
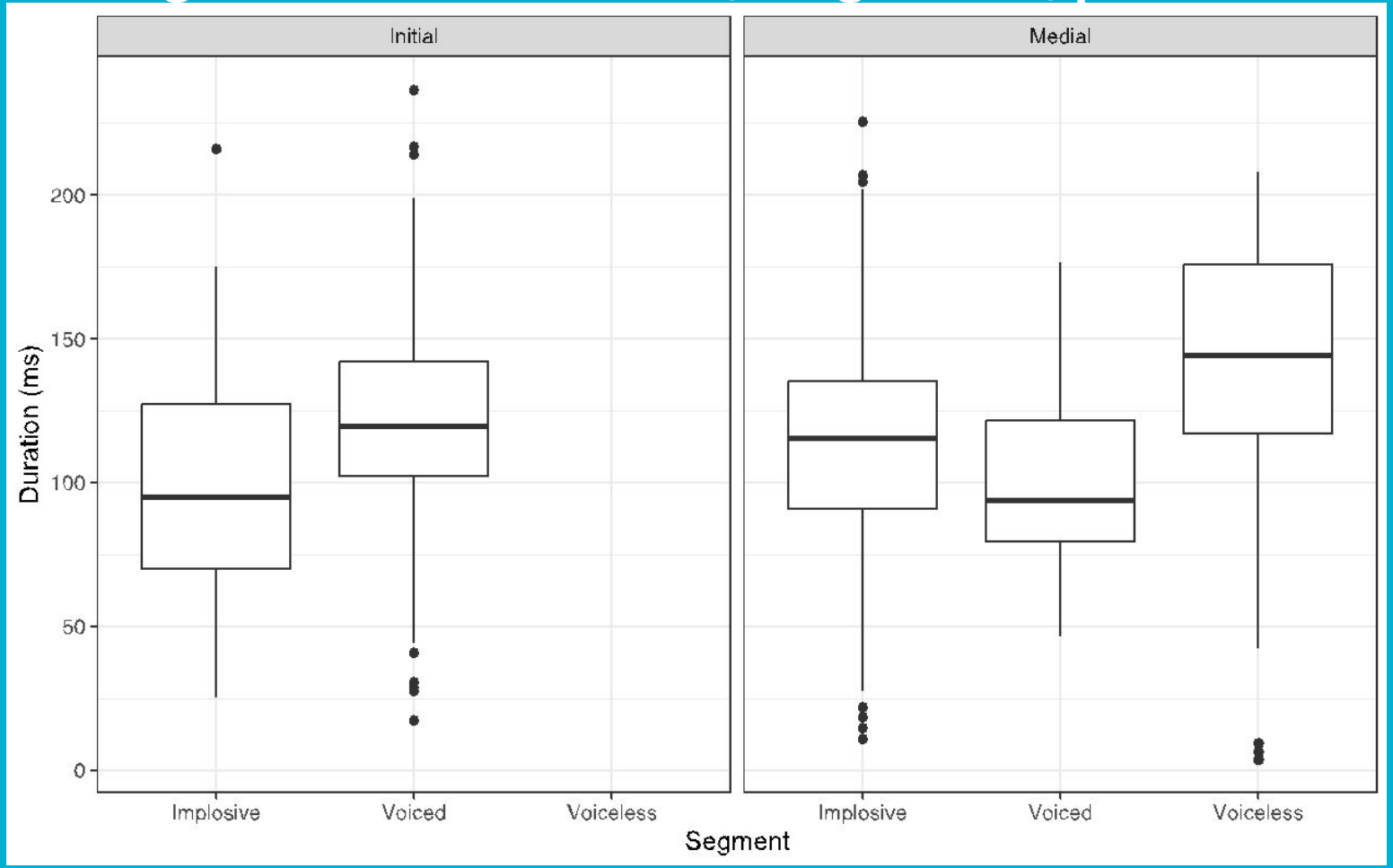


Prevoicing/ Closure-Duration by Segment Type and Position



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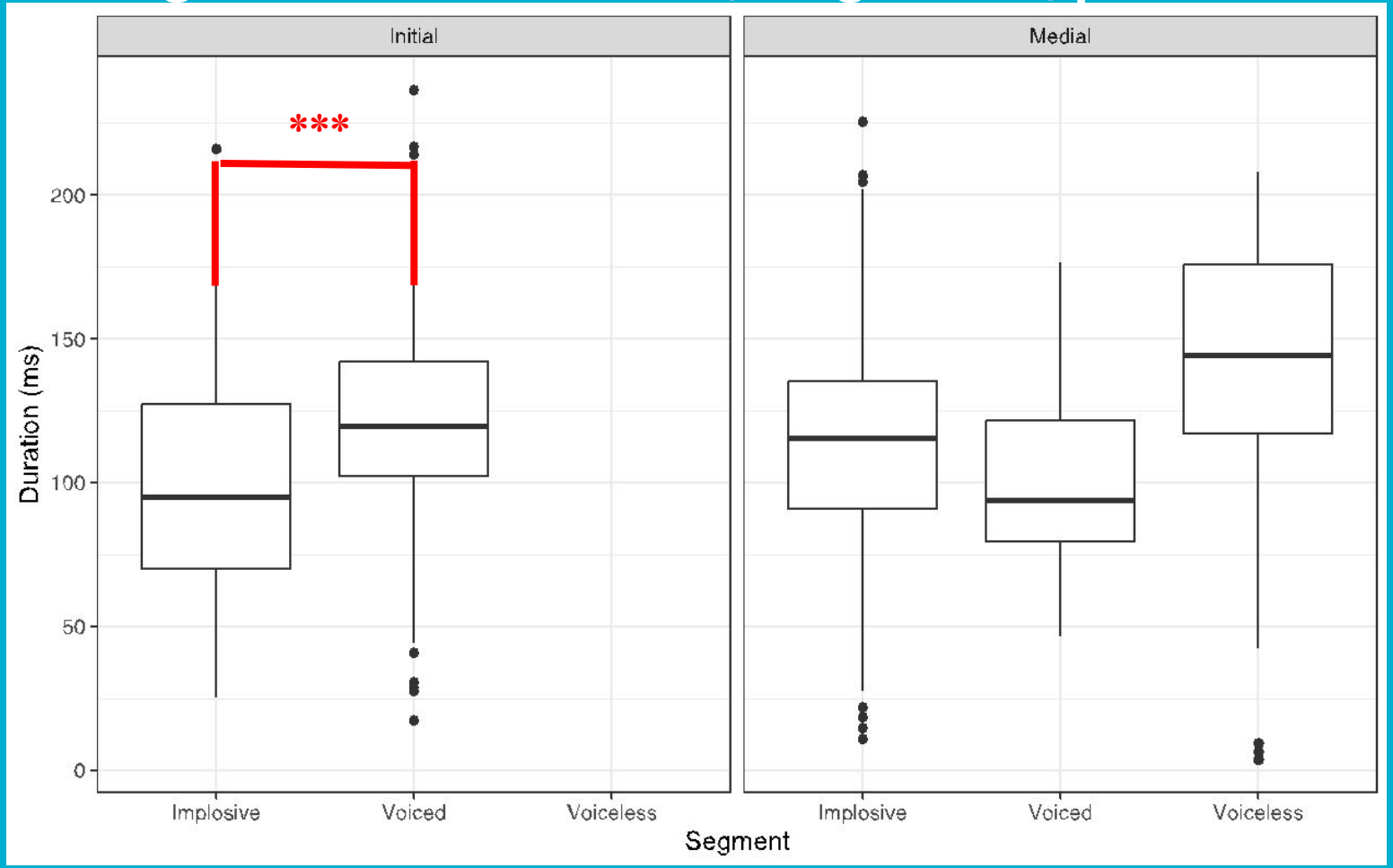

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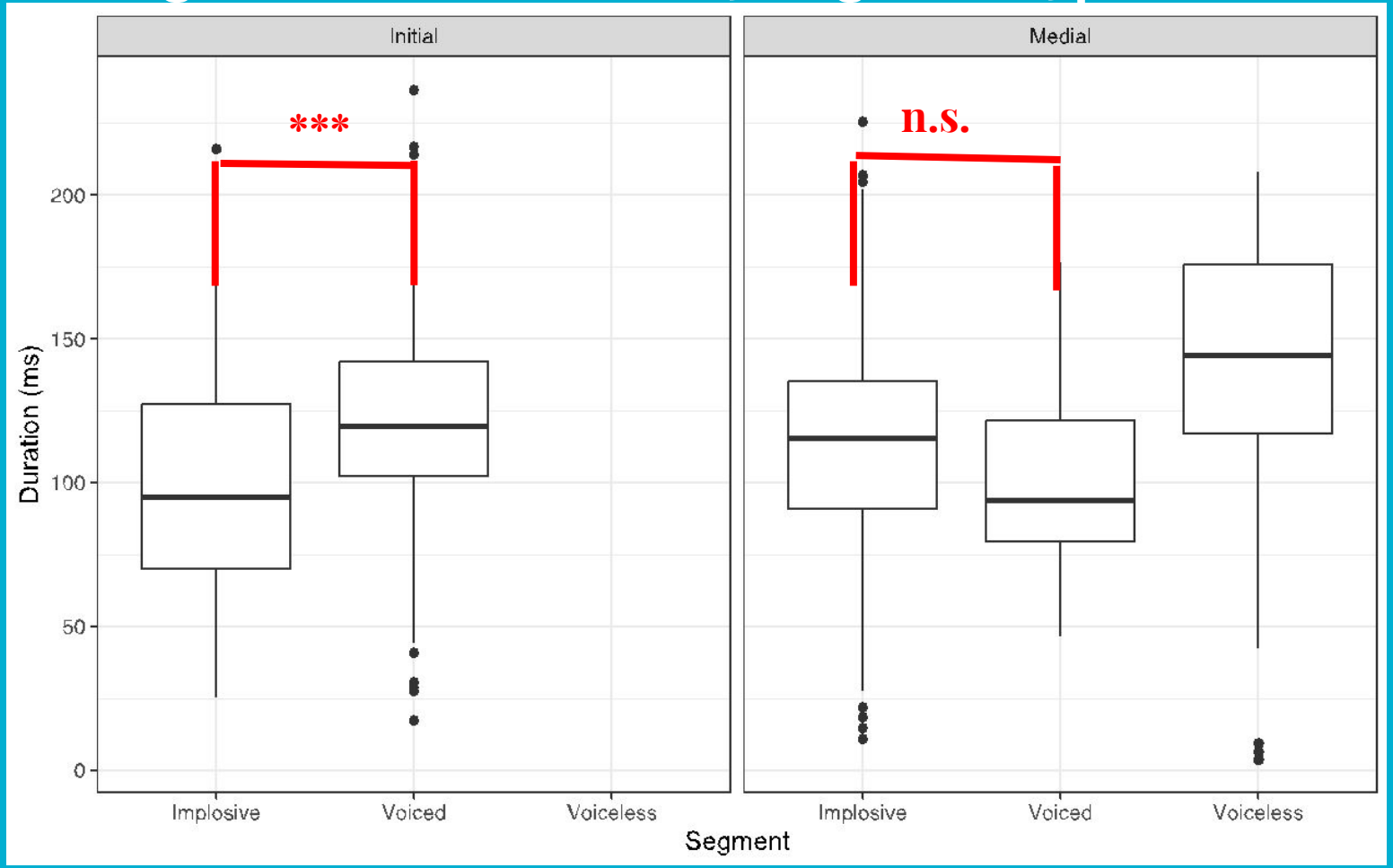

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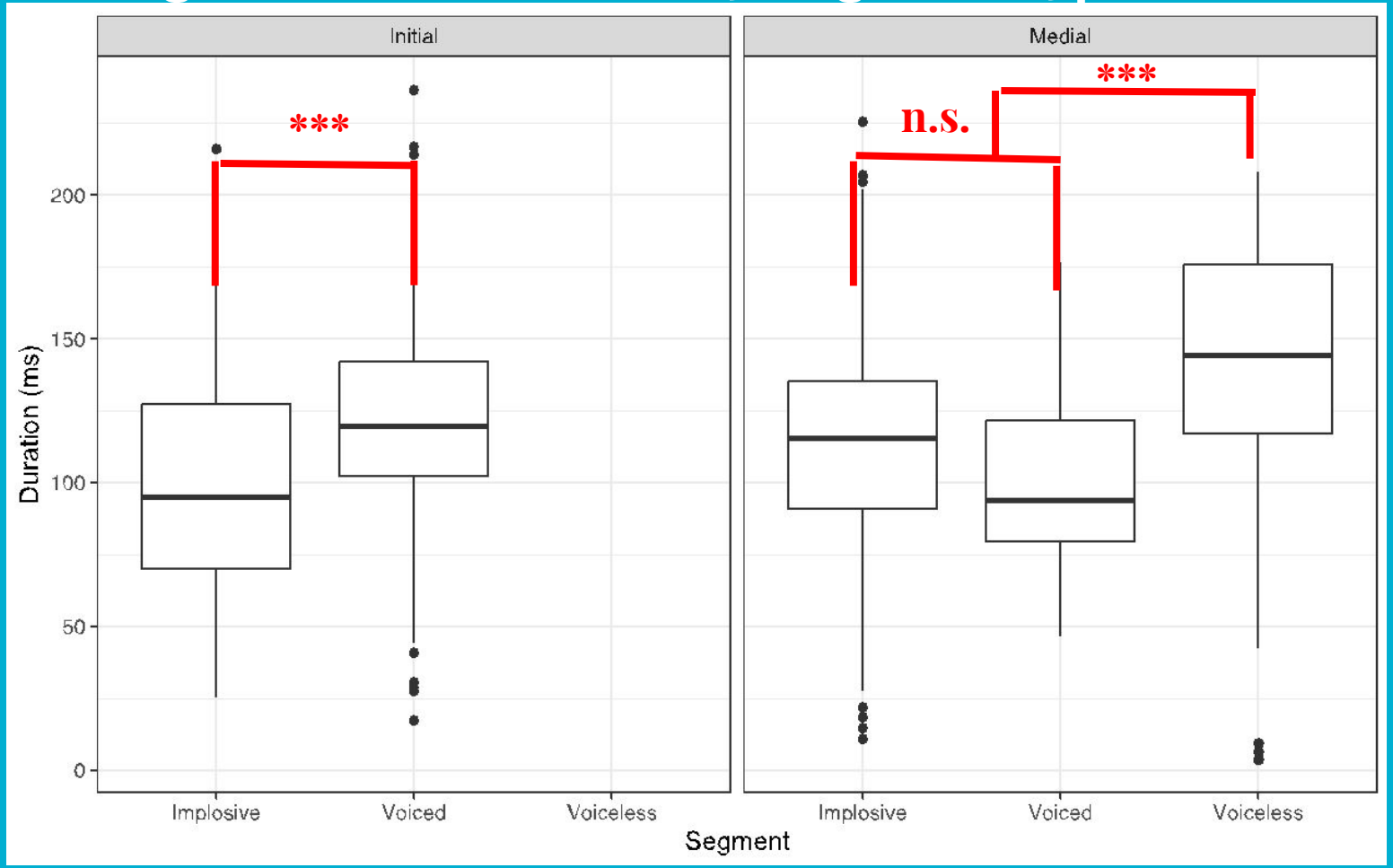
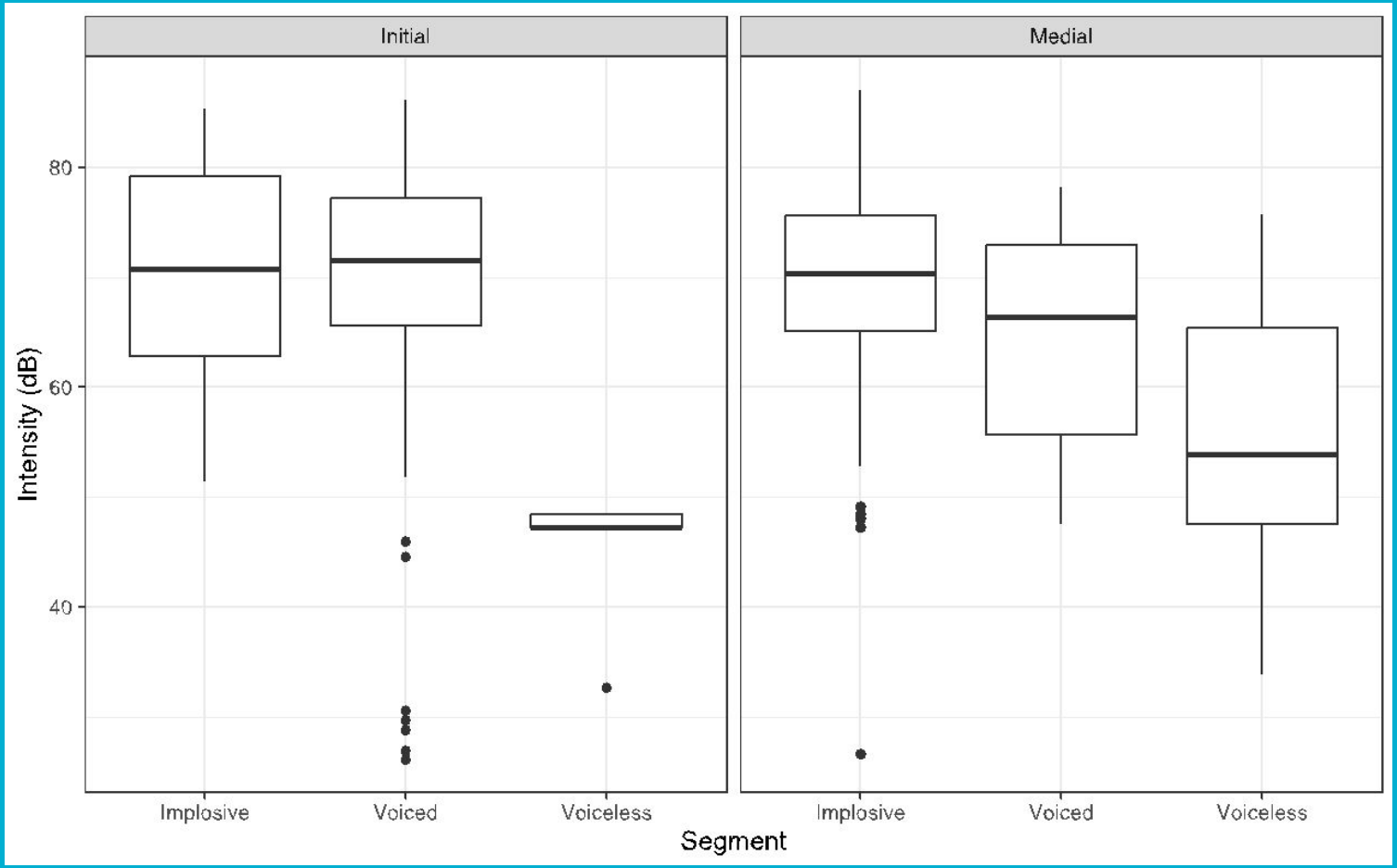


Intensity of Prevoicing by Segment Type and Position



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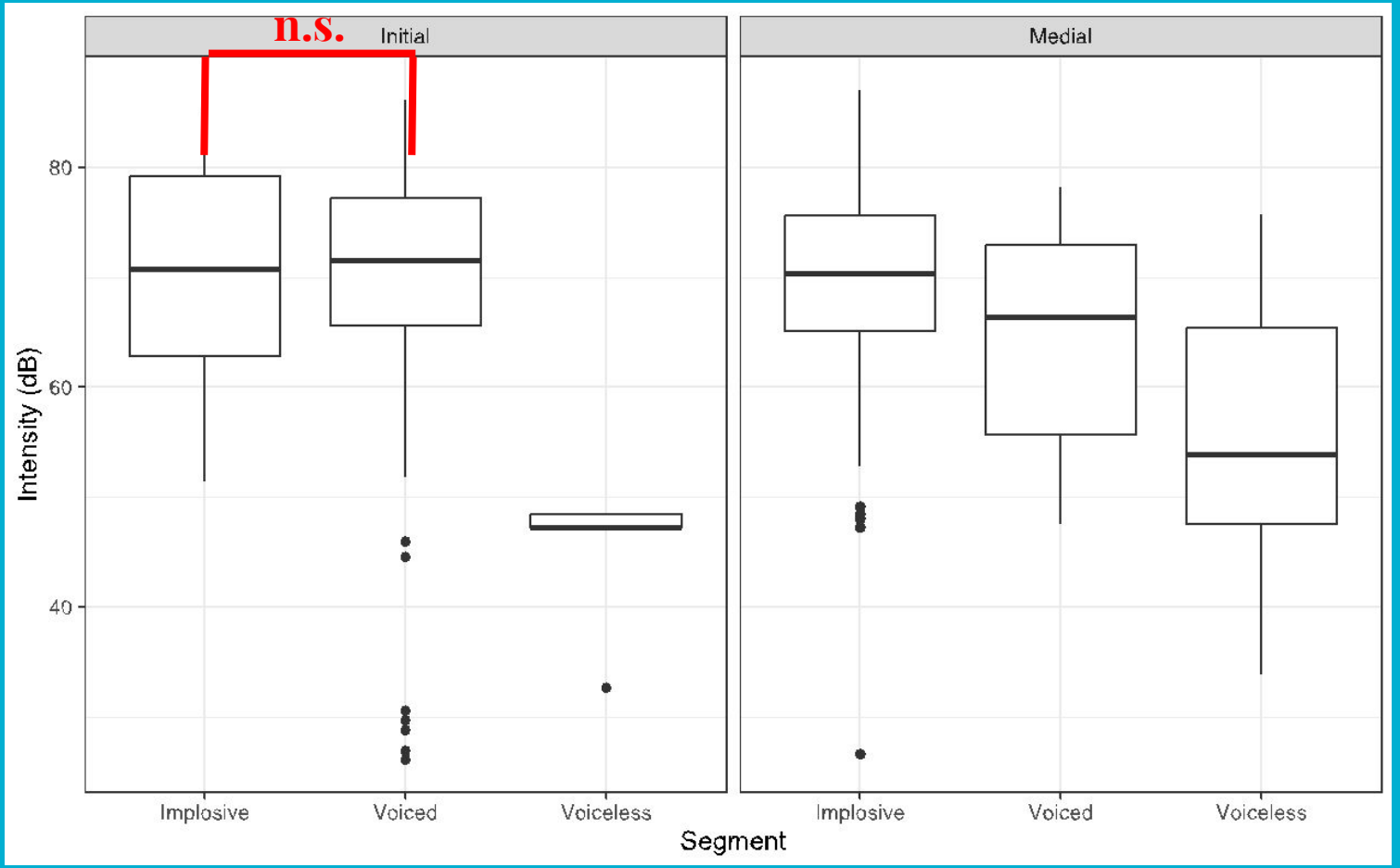
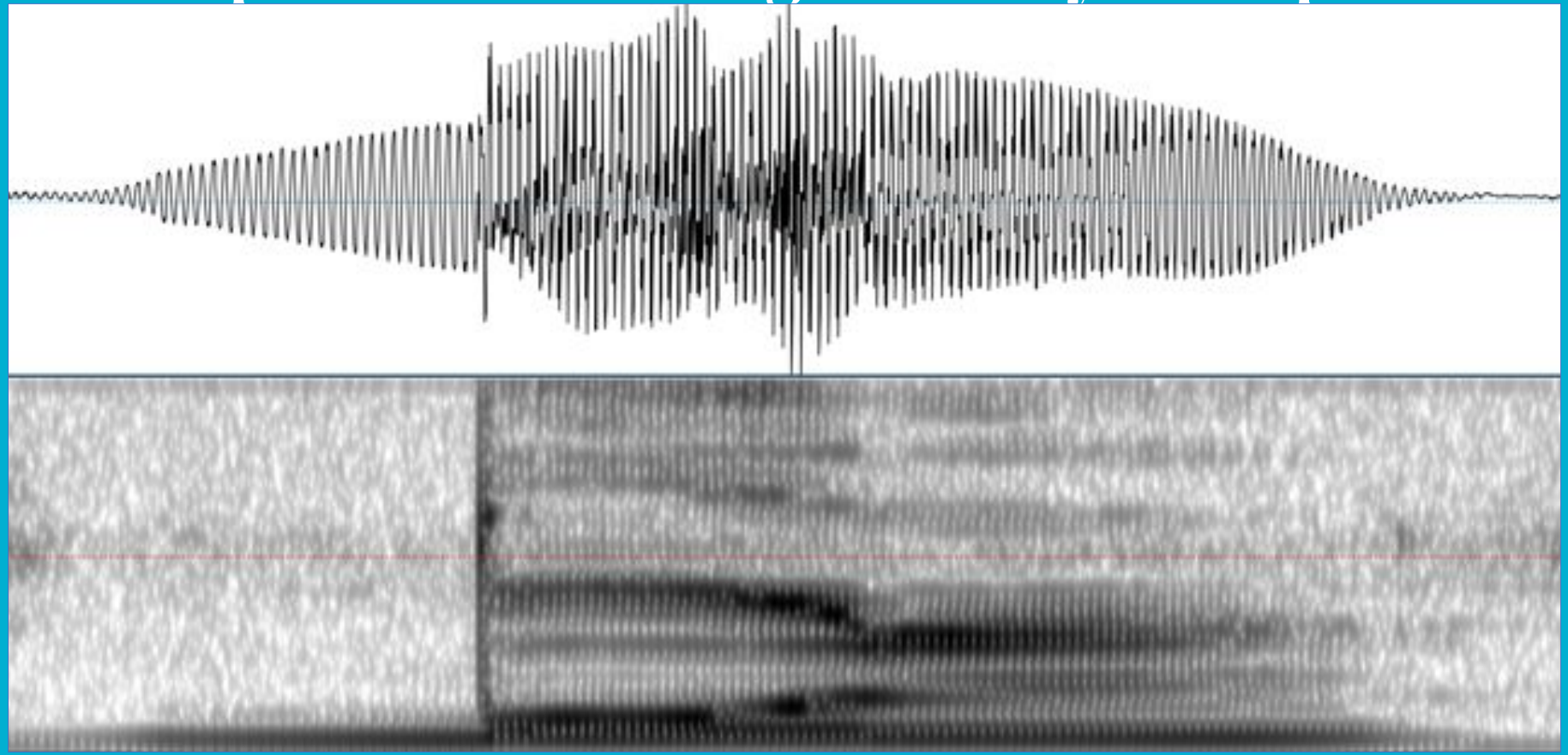
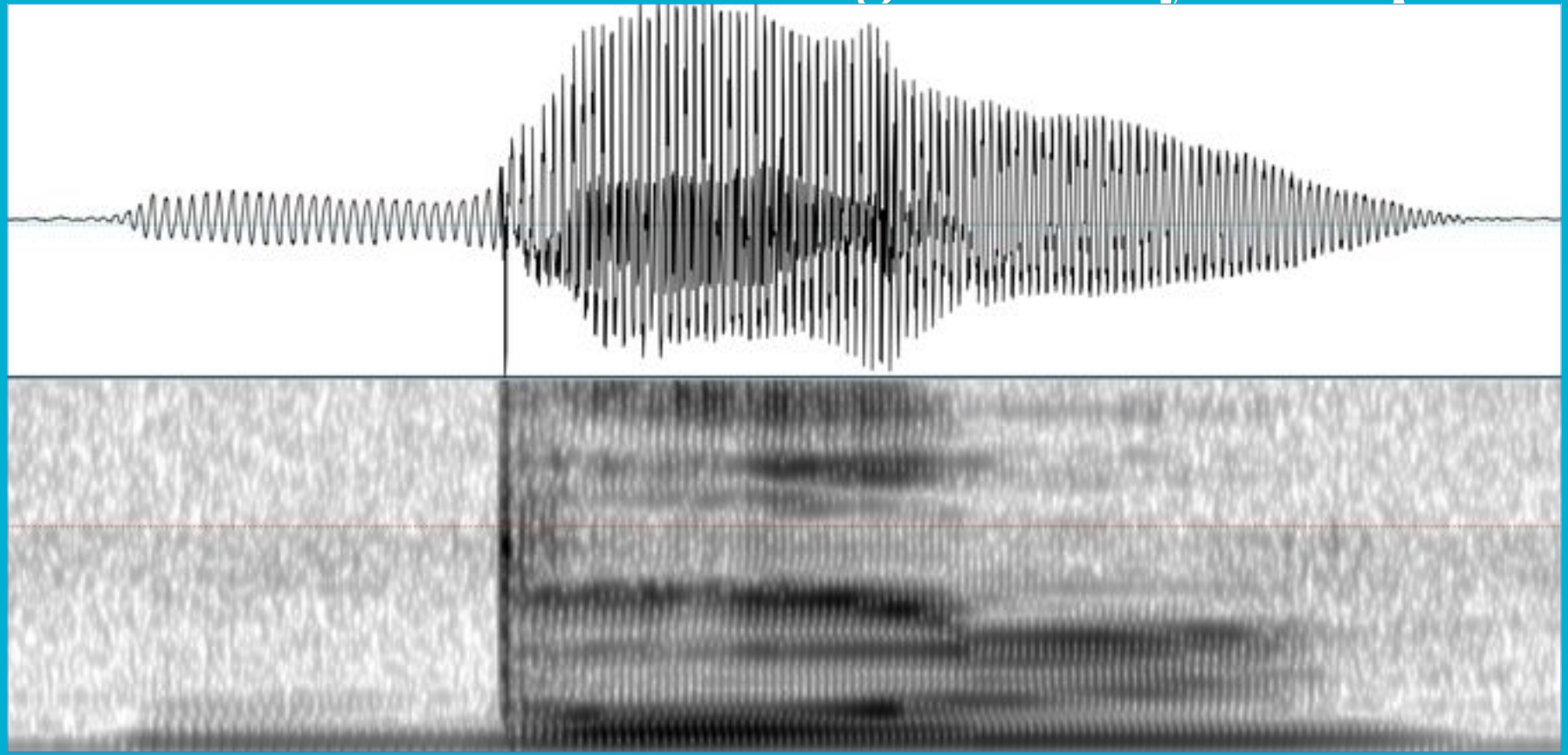


Implosive Prevoicing Intensity Example



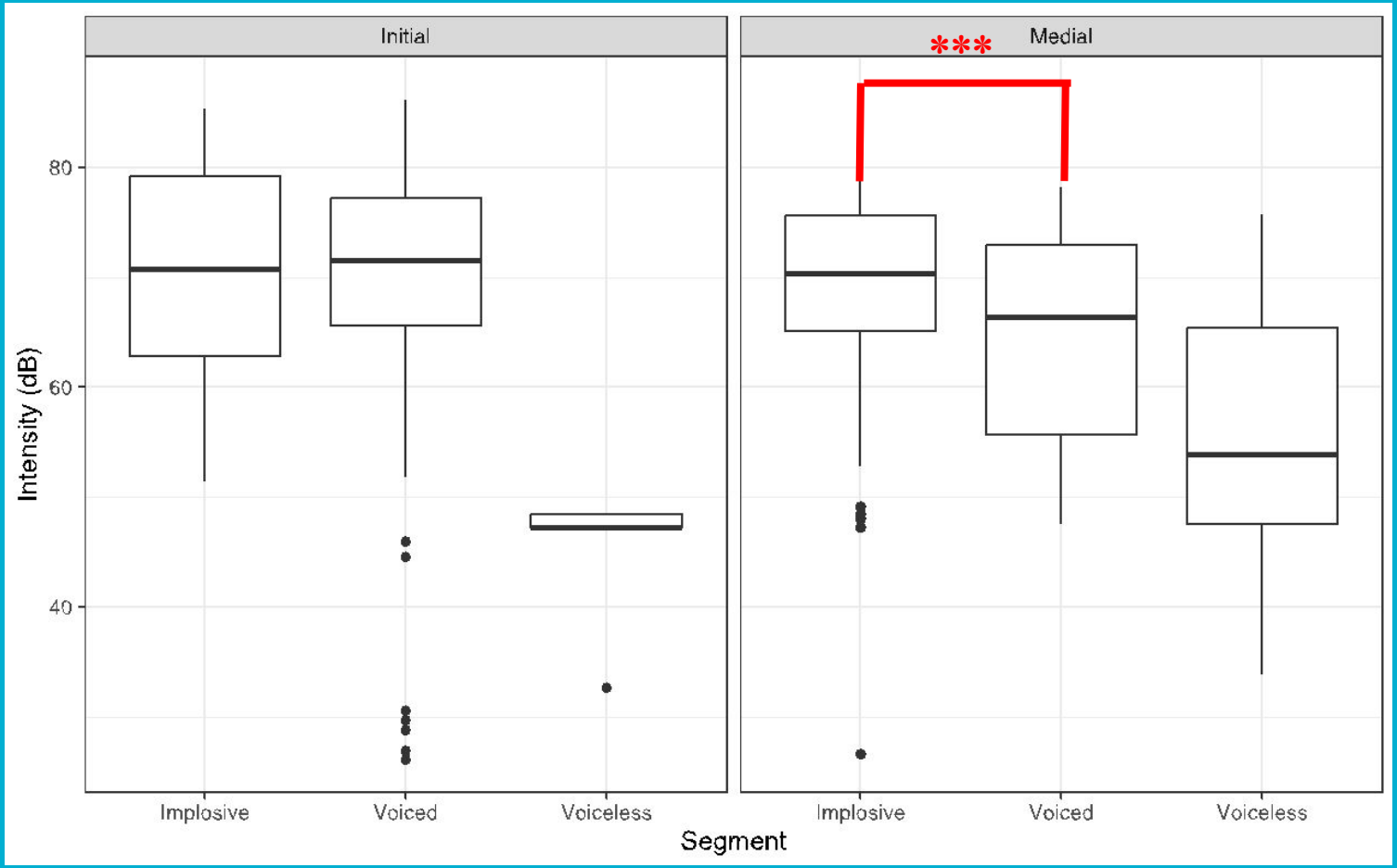
ɓúl *snail*

Voiced Plosive Prevoicing Intensity Example

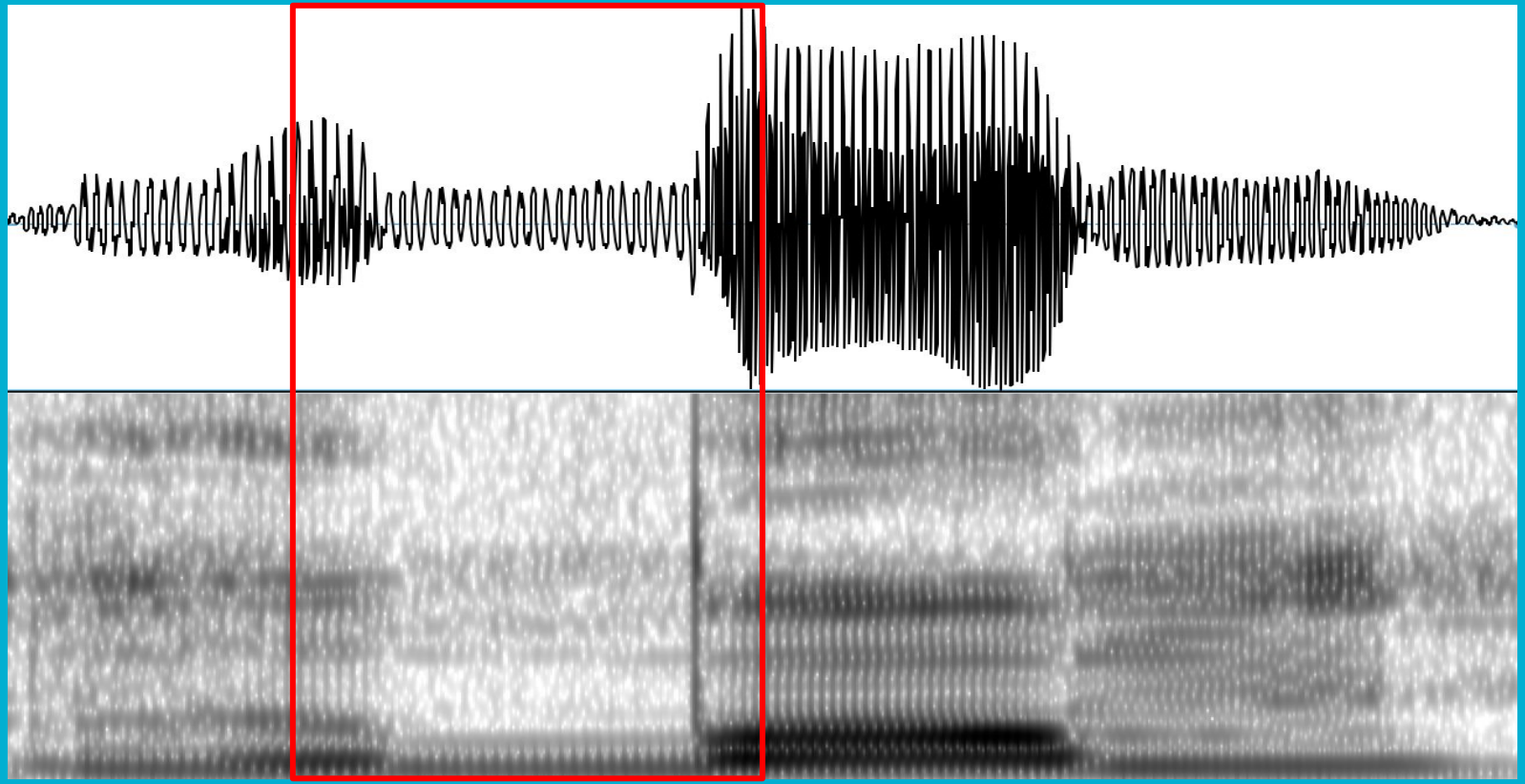


búl ***Goat***

Intensity of Prevoicing by Segment Type and Position



Medial Implosive Prevoicing Intensity Example



ʀɨ̀ɓóm *Furrow*

Discussion

Summary of Results:

- **Vowel Fundamental Frequency:**
  - High Tone: Consistent with past findings: implosives higher than voiced; different from past findings: equal to voiceless
  - Low Tone: No difference between voiced and implosives; both lower than voiceless
- **Closure Duration:**
  - Initial Position: Implosives significantly shorter
  - Medial Position: Both implosives and voiced plosives shorter than voiceless
- **Prevoicing Intensity:**
  - Initial Position: No significant difference, but rising intensity slope for implosives
  - Medial Position: Implosives significantly higher, but no rise in intensity slope for implosives

Articulatory Features of Implosives

- **Larynx lowering and airstream mechanism** *(Painter 1977)*
  - Higher fo following implosive compared to voiced plosive
  - Rising intensity during implosive closure (initial position)
- **Implosives pattern acoustically more like voiced plosives in medial position**
  - Similar closure duration lengths
  - No rise in closure intensity (although implosive intensity still higher)
- **Potentially more vocal fold tension during implosive production**
  - Implosive and voiceless plosive similar fo in high tone environment
  - However, low tone environment shows this pattern of higher vocal fold tension is not consistent
- **Difference in prevoicing duration could reflect difference in sonority**
  - Guébe language showed longer durations than voiced plosives
    - Implosives patterned more with sonorants
  - Shorter duration could be phonetic marker of more obstruent-like qualities?

Phonological Qualities of Implosives

- Pattern more consistently with obstruents
  - **Syllable position:**
    - Implosives can occur in both onset and coda position along with plosives (e.g. **ɓ**ó**ŋ**á,tù**ɓ; b**òm,kò**p)**
    - Most sonorants (/w/,/ʁ/,/j/) only occur in onsets; laterals and nasals are exceptions
  - **Prenasalization:**
    - Implosives and plosives can both be prenasalized (though so can most sonorants)

Conclusion

- Phonetic features shown through acoustic analysis:
  - Lowered larynx↠ rising intensity slope
  - Stiffened vocal folds↠ higher fo (more-so in high tone condition)
- Showed signs of more plosive-like behavior through acoustic measures:
  - fo in low tone conditions
  - Prevoicing duration and intensity slope in word-medial positions
- Phonological Observations:
  - Coda syllable position↠ not all sonorants are seen in this position
  - Prenasalization↠ plosives prenasalized (though most sonorants are, too)
- Prediction: Rikpa implosives overall depict more obstruent-like behavior than sonorant-like behavior

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