True voiced aspirates in Yemba

i.e. truly *voiced and* truly *aspirated*

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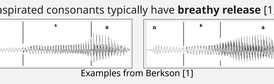
"Voiced aspirated" consonants

Voiced aspirated consonants typically have **breathy release** [1, 6, 11]



Examples from Berkson [1]

A longstanding claim by Ladefoged [7]; a **voiced consonant** with **voiceless aspirated release** is not a possible speech sound:

- "a sound in which the vocal cords are vibrating during the articulation and then come apart into the voiceless position during the release of the stricture … has not yet been observed in any language"
- Some purported counterexamples [4], but little phonetic data available

We provide evidence that **Yemba** (Grassfields Bantu, Cameroon) has precisely this type of segment: **voiced during closure, with voiceless aspiration at release**

Yemba voiced aspirates

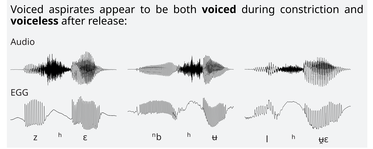
In Yemba, **most consonants** can be aspirated, including voiced fricatives, nasals, and approximants [2]

	Labial	Alveolar	Palatal	Velar	Glottal
Stop	p	t		k	ʔ
Affricate	pf	ts	tʃ		
Fricative	f v	s z	ʃ ʒ		(h)
Nasal	m	n		ŋ	
Approx.	w	l	j	ɥ	

V'less, can be aspirated
Voiced, can be aspirated
Cannot be aspirated

- Voiced prenasalized stops [ᵐb, ⁿd, ᵑg] also occur as realizations of nasal + /p, l, ɥ/

Voiced aspirates appear to be both **voiced** during constriction and **voiceless** after release:



Research goals

Using acoustic and EGG data, characterize **voicing in each (sub)segment** that might cue aspiration contrast in voiced aspirates

C h V

Q1 Is the phonation associated with **constriction** rather truly **voiced** rather than partly devoiced?

Q2 Is the phonation associated with **release** truly **voiceless** rather than breathy?

Q3 Is the aspiration contrast also realized after aspiration ends (as **breathiness**)?

Does this vary according to **consonant manner?**

Materials, methods

Four native speaker participants (1F, 3M); two drawn from audio/EGG lexicon in [3]

Materials contained voiced aspirated consonants and their unaspirated equivalents in open syllables

- **Prenasalized stops**: [ᵐb ⁿd ᵑg] vs. [ᵐbʰ ⁿdʰ ᵑgʰ]
- **Fricatives**: [v z ʒ] vs. [vʰ zʰ ʒʰ]; all may also be **prenasalized**
- **Approximants**: [w l ɥ] vs. [wʰ lʰ ɥʰ]

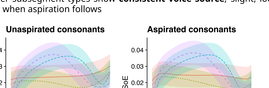
Simultaneous **audio** and **EGG** (for three of four speakers) collected

- **Strength of excitation** (SoE) calculated as measure of voice source strength [10, 9]
- Measures of breathiness: **closure quotient** (**CQ**) from EGG signal; **cepstral peak prominence** (**CPP**) and **H1*-A3*** from acoustics [6, 1]
  - Acoustic measures not calculated for fricatives: varying fricative noise sources are confound

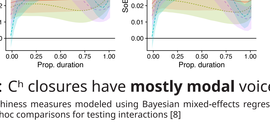
Q1-2: Cʰ aspiration is **voiceless**; closures **voiced**

Strength of excitation (SoE) over time for different (sub)segment manners assessed using **GAMMs** [12]: SoE ~ MANNER*TIME + (1 |SPEAKER)

- Aspiration's 95% CI intervals overlap 0 SoE for most of duration; suggests **no voice source** present in signal
- Tendency for weak voice source to be present near preceding consonant closure



- Other subsegment types show **consistent voice source**; slight, local lowering of SoE when aspiration follows



Q1: Cʰ closures have **mostly modal** voice

Breathiness measures modeled using Bayesian mixed-effects regressions [5], with post-hoc comparisons for testing interactions [8]

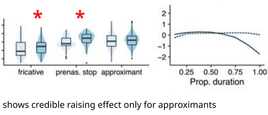
- For each measure, MEASURE ~ ASPIRATION*MANNER + (1 |SPEAKER)
- Weak uninformative prior used (no expectations from existing literature)

Credible main effect of **aspiration** found for all voicing measures, suggesting consonant voicing is breathier before aspiration.

- **CQ lowered:** less vocal contact preceding aspiration
- **CPP lowered:** noisier, weaker harmonic structure preceding voicing
- **H1*-A3*:** higher spectral tilt pre-aspiration

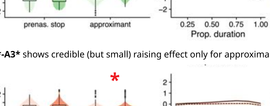
Credible interaction effects (credible post-hoc comparisons marked with *) suggest manner-specific effects of aspiration on voicing

- **CQ** lowers more during aspirated fricatives and stops

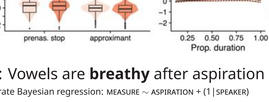


- **Timecourse data** suggests this is coarticulatory; not distributed across duration

- **CPP** shows credible raising effect only for approximants



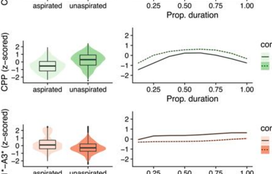
- **H1*-A3*** shows credible (but small) raising effect only for approximants

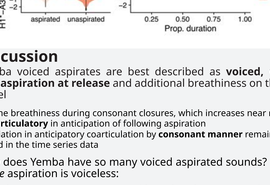


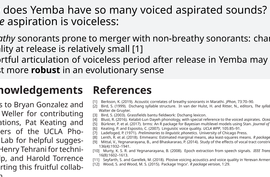
Q3: Vowels are **breathy** after aspiration

Separate Bayesian regression: MEASURE ~ ASPIRATION + (1 |SPEAKER)

Credible effects of aspiration for vowels on **CQ**, **CPP**, and **H1*-A3***: post-aspiration voicing is breathier across **entire duration**







Discussion

Yemba voiced aspirates are best described as **voiced, with voiceless aspiration at release** and additional breathiness on the following vowel

- Some breathiness during consonant closures, which increases near release; seems **coarticulatory** in anticipation of following aspiration
- Variation in anticipatory coarticulation by **consonant manner** remains to be examined in the time series data

How does Yemba have so many voiced aspirated sounds? Perhaps *because* aspiration is voiceless:

- *Breathy* sonorants prone to merger with non-breathy sonorants: change in acoustic quality at release is relatively small [1]
- Effortful articulation of voiceless period after release in Yemba may make the contrast more **robust** in an evolutionary sense

Acknowledgements

Thanks to Bryan Gonzalez and James Weller for contributing annotations, Pat Keating and members of the UCLA Phonetics Lab for helpful suggestions, Henry Tehrani for technical help, and Harold Torrence for starting this fruitful collaboration.

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