Phonetics of voiced aspirates in Yemba (Dschang)

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"Voiced aspirated" consonants

Not actually voiced, then (voicelessly) aspirated: **breathy** phonation present during/after release\(^1\)

» For example, Owerri Igbo\(^2\)

/d/ \[\text{idè}\] ‘write’

\[\text{breathy}\]

/d\(^h\)/ \[\text{údè}\] ‘boom’

\[\text{modal}\]

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\(^1\) Berkson, 2019; Keating and Esposito, 2007; Seyfarth and Gareleke, 2018.

\(^2\) rec. Ladefoged and Keating 1984, UCLA Phonetics Archive.
A claim about consonant voicing

No truly **voiced, then voiceless aspirated** consonants

» “[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” (Ladefoged)³

* ![Diagram of C with [+voi] and [-voi] branches]

» Some purported examples, but closer examination disproves them⁴

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Yemba voiced aspirates

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This talk: counterevidence

Our claim:
» Voiced aspirates in **Yemba** have precisely this sort of laryngeal timing: *voicing during closure* and *voiceless aspiration* post-release

Outline
» Yemba description
  » Consonant inventory
  » Qualitative description of $C^h$

» EGG/audio study
  » Presence of voicing
  » Quality of voicing

» Discussion
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About Yemba
About Yemba AKA Dschang

» Bamileke (Grassfields Bantu) language spoken in West region of Cameroon by 300,000-400,000 people\(^5\)

\(^5\)Eberhard, Simons, and Fennig, 2021.

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Yemba voiced aspirates
Most consonants have aspirated and unaspirated counterparts, including voiced fricatives, nasals, and approximants\textsuperscript{6}

<table>
<thead>
<tr>
<th></th>
<th>Labial</th>
<th>Alveolar</th>
<th>Palatal</th>
<th>Velar</th>
<th>Glottal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stop</td>
<td>p p\textsuperscript{h}</td>
<td>t t\textsuperscript{h}</td>
<td>k k\textsuperscript{h}</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>Affricate</td>
<td>pf pf\textsuperscript{h}</td>
<td>ts ts\textsuperscript{h}</td>
<td>tf tf\textsuperscript{h}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fricative</td>
<td>f f\textsuperscript{h} v v\textsuperscript{h}</td>
<td>s s\textsuperscript{h} z z\textsuperscript{h}</td>
<td>j j\textsuperscript{h} 3 3\textsuperscript{h}</td>
<td>(h)</td>
<td></td>
</tr>
<tr>
<td>Nasal</td>
<td>m m\textsuperscript{h}</td>
<td>n n\textsuperscript{h}</td>
<td></td>
<td></td>
<td>η</td>
</tr>
<tr>
<td>Approx.</td>
<td>w w\textsuperscript{h}</td>
<td>l l\textsuperscript{h}</td>
<td>j</td>
<td></td>
<td>ω ω\textsuperscript{h}</td>
</tr>
</tbody>
</table>

\textsuperscript{6}Bird, 1999.
Yemba consonant inventory

Derived voiced prenasalized stops also occur:

» Unaspirated \[^n\text{b}, n\text{d}, n\text{g}, n\text{gw}\] from nasal + /p, l, υ, w/

\begin{align*}
n- \text{‘CL6’} + -\text{pi} & \quad \text{‘liver’} & \rightarrow & \text{nbi} \\
n- \text{‘INF’} + -\text{lυ} & \quad \text{‘rain (v.)’} & \rightarrow & \text{ndu} \\
n- \text{‘CL1’} + -\text{uŋwə} & \quad \text{‘stranger’} & \rightarrow & \text{nɡwə} \\
n- \text{‘INF’} + -\text{wɛ} & \quad \text{‘have; get’} & \rightarrow & \text{nɡwɛ}
\end{align*}

» Aspirated \[^n\text{b}^h, n\text{d}^h, n\text{g}^h, n\text{g}^hw\] from /p^h, l^h, υ^h, w^h/

\begin{align*}
n- \text{‘INF’} + -\text{p}^h\text{i} & \quad \text{‘sow’} & \rightarrow & \text{nbi} \\
n- \text{‘INF’} + -\text{l}^h\text{u} & \quad \text{‘wrestle’} & \rightarrow & \text{ndu} \\
n- \text{‘INF’} + -\text{u}^h\text{u} & \quad \text{‘do’} & \rightarrow & \text{nɡu} \\
n- \text{‘CL9’} + -\text{w}^h\text{i} & \quad \text{‘deer’} & \rightarrow & \text{nɡwi}
\end{align*}
Implementation

Aspiration appears **voiceless**, even after voiced consonant constrictions

- Prenasalized voiced stops

\[ ndʉ 'string' \]

\[ nd^{h}ʉ 'boundary' \]
Implementation

Aspiration appears **voiceless**, even after voiced consonant constrictions

» Voiced approximants

\[ \text{lʉ ‘horse’} \]

\[ \text{məlʰʉ ‘soldier ants’} \]
Different implementation strategies

Aspiration appears **voiceless**, even after voiced consonant constrictions

» Voiced fricatives (may also be prenasalized; not shown)

» Often a voiceless extension of the onset fricative, e.g. \( /z^h/ \) as [zs]; as reported for Ngyembɔɔn

\[ \text{ləzɛ ‘grass’} \]

\[ \text{ləz^hɛ ‘know’} \]

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Comparison with breathy Cs

Contrast [ⁿdʰ] with Owerri Igbo /dʰ/

» Igbo implements voiced aspirated consonants as **breathy**
» Yemba appears to implement **distinct** period of **voicelessness**
Phonetic study
Recap: study goals

We propose that voiced aspirates in Yemba are voiced during closure with voiceless aspiration at and after release

Goals:

» Characterize voicing in each subsegment of voiced aspirates using audio and EGG
  » Strength of voice source
  » Phonation type, where present
  » During closure, after release

» Characterize voice quality of vowels following aspiration
Speakers and materials

» Four native speakers (1F, 3M)
  » 1M, 1F lab-recorded (UCLA, late 2019)
  » 2M from pre-existing audio lexicon

» Materials collected contained voiced {aspirated, unaspirated} consonants
  » Prenasalized stops: [ⁿb ⁿd ⁿg] vs. [ⁿbʰ ⁿdʰ ⁿgʰ]
  » Fricatives: [v z ʒ] vs. [vʰ zʰ ʒʰ]; all may also be prenasalized
  » Approximants: [w l ʊ] vs. [wʰ lʰ ʊʰ]

» Total $n = 2,022$ (sub)segments
  » Lab speakers: 391, balanced list and frame sentence
  » Corpus speakers: 1,631, opportunistic search through lexicon

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Yemba voiced aspirates
Methods and measurements

» Simultaneous audio and EGG collected (for three of four speakers)
  » EGG for both lab speakers and one lexicon speaker
» Manual segmentation into C, h, V according to audio
» Voice quality measures calculated in Voicesauce
  » **Strength of excitation (SoE):** measure of voice source strength
  » Measures of breathiness: **contact quotient (CQ)** from EGG signal; **cepstral peak prominence (CPP)** and **H1*-A3* from acoustics**
» CPP, H1*-A3* not calculated for fricatives
» No VQ measures calculated for aspiration

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9Mittal, Yegnanarayana, and Bhaskararao, 2014; Murty and Yegnanarayana, 2008.
Analysis

**SoE:** duration-normalized *time series* submitted to AR1 generalized additive mixed models (GAMMs)

» Convey typical voice source dynamics in $C^hV$ sequences

» $\text{SOE} \sim \text{MANNER} \times \text{ASPIRATION}$, random smooths by speaker

**VQ measures:** z-scored; mean of time series submitted to Bayesian mixed-effects regression

» Simpler measure of degree of breathiness in flanking Cs and Vs

» Separate models for each of CQ, H1*-A3*, CPP

» Weak uninformative prior

» Structure: $\text{MEASURE} \sim \text{MANNER} \times \text{ASPIRATION}$, random intercepts by speaker
**Analysis**

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- **Structure:** $\text{MEASURE} \sim \text{MANNER} \times \text{ASPIRATION}$, random intercepts by speaker
Results: SoE

(strength of voice source: C, h, V)
Consonant SoE by manner

» Voice source (modulo manner effects on SoE) is present
Vowel SoE by preceding C manner

» Longer-range effect on voice source visible in V

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Aspiration SoE, by preceding C manner

» Very weak or no voice source in post-release aspiration

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Results: VQ measures

(breathiness: C, V)
Consonant CQ, by manner

- **Credible main effect** of aspiration (and interactions *)
- **Lower CQ** preceding aspiration: less vocal fold contact

![Box plots showing CQ by manner](image)

- Time series suggest: mainly *immediately* preceding aspiration, except for oral fricatives

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Yemba voiced aspirates
Consonant CPP and H1*-A3*, by manner

» Credible main effects of aspiration for both (and interactions *)

» CPP lowered before aspiration: noisier harmonic structure

» H1*-A3* raised before aspiration: greater spectral tilt
» **Credible effect** of aspiration for all measures
» Time series suggest breathiness over entire following vowel
Discussion
Summary

Yemba voiced aspirates exhibit mostly modal voicing in C constriction, followed by voiceless, spread-glottis target for aspiration.

SoE timecourses suggest:

» Little to no voicing energy present in aspiration
» Near aspiration, local anticipation of spread-glottis in C constriction; longer-distance spread glottis through V

Voice quality measures suggest:

» Vs following aspiration are breathy
» Preceding C constrictions are less affected
Architectural implications

Reinforces the need for ordered sub-segmental representations to reflect production\textsuperscript{11}

\[ \begin{array}{c}
\text{C}^h \\
\text{V}
\end{array} \quad \begin{array}{c}
[+\text{voi}] \\
[-\text{voi}]
\end{array} \]

Re-evaluate complex segments with mixed voicing or "phonation contour", particularly in African languages

» Ju voiced-voiceless stops, affricates\textsuperscript{12}

» Tuu voiced + glottalized ([dts']) etc.\textsuperscript{13}

» Igbo and Sereer voiceless implosives\textsuperscript{14}

\textsuperscript{11}Inkelas and Shih, 2016.
\textsuperscript{12}Gerlach, 2016.
\textsuperscript{13}Miller et al., 2009; Nakagawa, 2010.
\textsuperscript{14}Ikekeonwu, 1985; Ladefoged, Williamson, Elugbe, and Uwulaka, 1976; McLaughlin, 2005.
The **other Bamileke languages** have similar aspiration\(^{15}\)

- “Aspiration” often develops into fricative release matching C’s place (as Yemba fricatives have)
- Aspiration/affrication is *always voiceless* release, even after [+voi] C
  - Ghomálá’ /tʰ/ in [tʰə] ‘head’
  - Ngyembɔɔn /nɡʰ/ in [n̪ɡɔ̱xe] ‘dogs’

**Why is [+voi][-voi] stable once it develops?**

- Voiceless implementation involves large, effortful modulation of voice quality; may be more consistently recoverable\(^{16}\)
- Breathy-modal voice contrasts in Cs tend to merge\(^{17}\)

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\(^{15}\)Anderson, 1982; Hyman, 1972; Nissim, 1981.

\(^{16}\)Ohala and Kawasaki-Fukumori, 1997.

\(^{17}\)Berkson, 2019.
Functional implications

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