Tongue root position and laryngeal state in Yemba vowels

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Overview

How do stop voicing and aspiration affect the shape of the supraglottal cavity in nearby vowels?

- Case study: Yemba (aka Dschang)

In this study, we use two types of data to investigate:

- Formant frequency data, for the effects in general
- Ultrasound data to directly observe tongue position specifically
Stop voicing and tongue position

Maintaining **voicing** during stops is difficult (Ohala, 1983 et seq)

- Pressure gradient across the glottis needed for the vocal folds to vibrate
- But stop closure causes pressure above/below glottis to equalize quickly

Solution: active **adjustment of cavity size** (Westerbury, 1982; Ahn 2015, 2018)

- Usually by **advancing tongue root** or **lowering tongue dorsum**
Aspiration and tongue position

Aspiration itself may also affect tongue position in a way that overlaps voicing effects (Ahn 2018)

- Compression of oral cavity may enhance aspiration (easier to achieve, louder)
- Aspiration’s laryngeal component may tug on tongue; “compromise” of tongue may facilitate aspiration
Separating voicing and aspiration effects

It is difficult to separate effects of aspiration and voicing, since these covary in many languages.

- See English: voiceless stops are also aspirated.

**Overlapping effects** on tongue root make it hard to pin down motivation for observed differences:

- Advancement for voiced, unaspirated stops?
- Retraction for voiceless, aspirated stops?
Yemba (aka Dschang)

Bamileke (Grassfields Bantu) language spoken by 300,000-400,000 people
Voicing and aspiration in Yemba

In Yemba, voicing and aspiration vary independently (Bird 1999)

<table>
<thead>
<tr>
<th></th>
<th>unaspirated</th>
<th>aspirated</th>
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</thead>
<tbody>
<tr>
<td>voiceless</td>
<td>[ⁿti] ‘write’</td>
<td>[ⁿtʰi] ‘host’</td>
</tr>
<tr>
<td>voiced</td>
<td>[ⁿdi] ‘lord’</td>
<td>[ⁿdʰi] ‘descendant’</td>
</tr>
</tbody>
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- Voiced aspirated stops are **voiced stops** followed by **voiceless aspiration**, not breathy stops as in many other languages
- This allows us to independently examine effects of voicing and aspiration
Acoustic methods

Corpus: Four speakers (3M, 1F)

- Two speakers were recorded at the UCLA Phonetics Lab
- Two speakers’ data taken from a previously recorded lexicon (Bird 2003)
  - 504 tokens analyzed in total
  - Vowels: /i/ /ʉ/ /u/; Stops: labial, coronal, velar (crossed aspiration and voicing)

Measurements: F1 and F2 measured at vowel midpoint using Parselmouth interface to Praat (Jadoul et al., 2018; Boersma & Weenink, 2021)

Analysis: Mixed effects Bayesian linear regression

- F1/F2 predicted by voicing, aspiration, their interaction, and vowel
- Random intercepts for speaker
Ultrasound methods

Midsagittal tongue ultrasound imaging recorded for 120 tokens (labial and coronal stops only, one speaker)

- Telemed Micro ultrasound device (83 frames per second)
- Held in place by an UltraFit stabilization headset (Spreafico et al. 2018)
- **Tongue surface contours** extracted using EdgeTrak (Li et al. 2005)
Ultrasound analysis

Smoothing-spline ANOVA (SSANOVA) in polar coordinates (Mielke, 2015)

- Provides modeled estimates of tongue surface position
- Dashed lines are 95% confidence intervals: if no overlap, there’s a statistically significant difference
- Anterior is to the right in these figures
Predictions: tongue position and effect on F1, F2

1. **Voicing**: active expansion entails
   - Tongue body lowering $\rightarrow$ **raised F1**
   - Tongue root advancement $\rightarrow$ **raised F2**

   **Prediction**: Voiced stops show raised F1 and raised F2 vs. voiceless

2. **Aspiration**: *if* aspiration entails oral cavity *compression*
   - Tongue body raising $\rightarrow$ **lowered F1**
   - Tongue root retraction $\rightarrow$ **lowered F2**

   **Prediction**: Aspirated stops show lowered F1 and lowered F2 vs. unaspirated
Results: vowel F1, F2 by speaker
Results: F1 effects

Voicing credibly raises F1, though the effect is small ($\beta=26$, CI=[8,44])

No interaction, but post-hoc comparisons show a larger effect for aspirated sounds

- Aspirated: $\beta=30$, CI=[2,57]
- Unaspirated: $\beta=21$, CI=[1,43]
- Just-noticeable difference for F1, F2 is about 20 Hz (Flanagan, 1955)

No effect of aspiration on F1 ($\beta=-3$, 95%CI=[-20,14])
Results: F2 effects

**Voicing** credibly raises F2 ($\beta=68$, CI=[25,110])

**Aspiration** credibly lowers F2 ($\beta=-64$, CI=[-104,-25])
Results: ultrasound

Vowel differences reflected in the data as expected
Results: effect of aspiration

Presence of **aspiration** has a consistent effect: tongue root retraction and/or tongue body lowering.
Results: effect of voicing

Presence of **voicing** has less of a consistent effect on lingual articulation

- Differences present tend to go *against* expectations: slight cavity constriction for voiced segments
Conclusions

Aspiration and voicing have small, separate acoustic effects on following vowels

- Voicing raises F1 and F2, suggests root advancement (and body lowering?)
- Aspiration lowers F2, suggesting root retraction
- Obvious potential implication for study of ATR contrasts

The actual lingual articulatory basis of these effects is less clear

- Ultrasound data show that aspiration effect is mainly due to root retraction
- Surprisingly, root retraction under aspiration has no effect on F1
  - In ATR harmony languages, [-ATR] set typically has higher F1 (Hess, 1992; Fulop et al., 1998; Kirkham & Nance, 2017)
- Voicing is not well reflected in lingual articulation
Outstanding questions and future work

We examined vowel **midpoints**. What does **stop release** look like, and how does retraction/advancement unfold **over time**?

- **Dynamic** measures (rather than single points in time)
- Voicing, *then* aspiration: might have affected voicing’s impact on vowel

Does **prenasalization** reduce voicing’s effect on tongue position?

- Venting pressure through open velum is another voicing maintenance strategy that does not involve the tongue (Ohala 1983, et seq)
- Voiced (purely oral) fricatives /v z ʒ/, which may also be aspirated, could be examined
Thank you!

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References


Appendix: vowels by speaker (Nearey normalized)