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

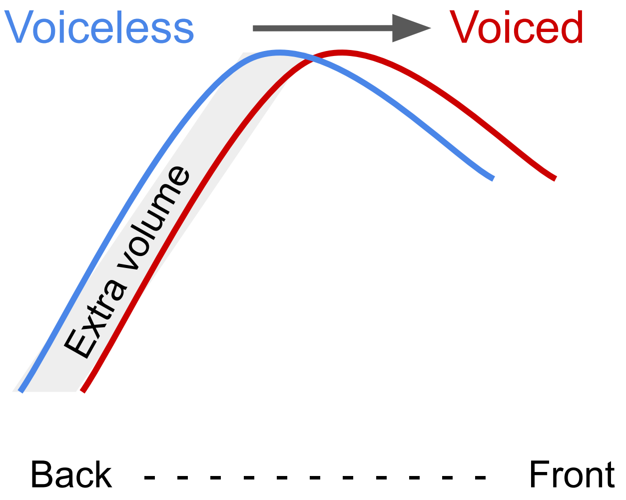
Stop voicing and tongue position

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)

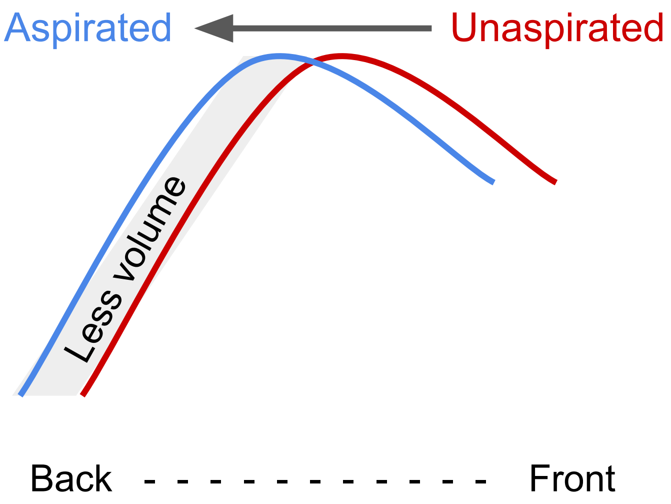
- Usually by **advancing tongue root** or **lowering tongue dorsum**



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



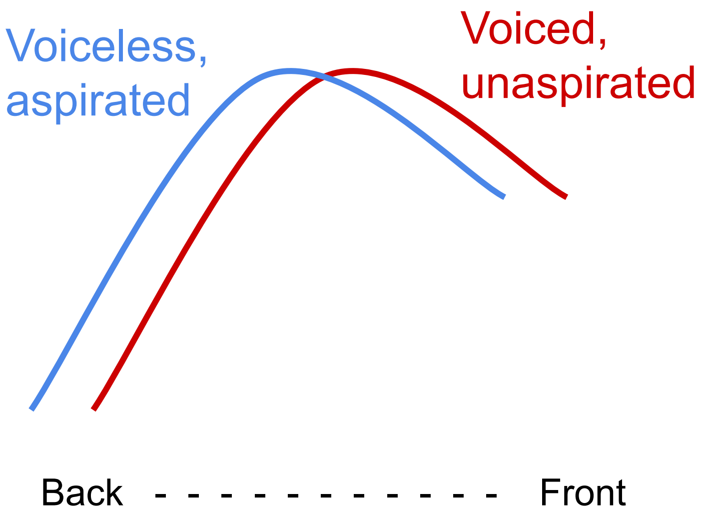
Separating voicing and aspiration effects

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

- See English: voiceless stops are also aspirated

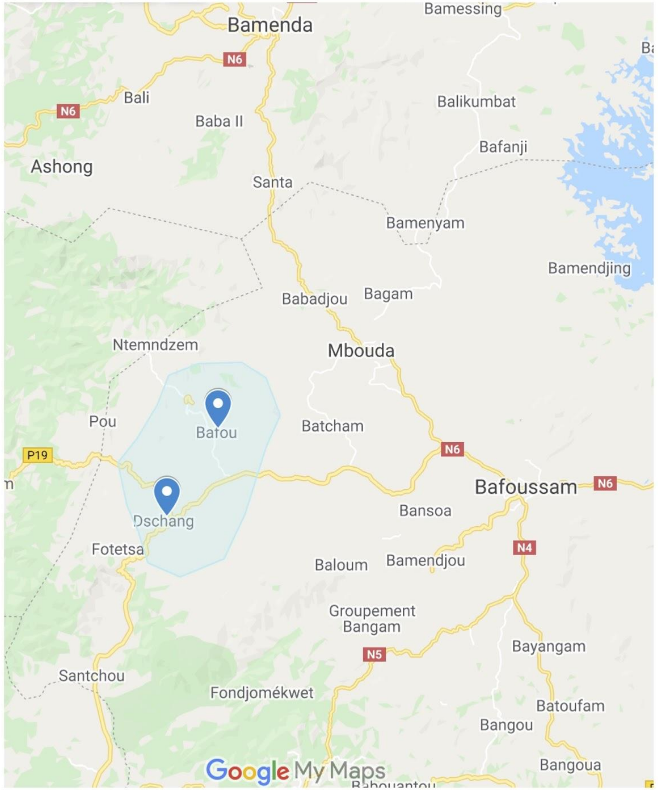
Overlapping effects on tongue root make it hard to pin down motivation for observed differences:

- 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)

	unaspirated	**aspirated**
voiceless	[^{n}**t**i] 'write'	[^{n}**t^{h}**i] 'host'
voiced	[^{n}**d**i] 'lord'	[^{n}**d^{h}**i] 'descendant'

- 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)

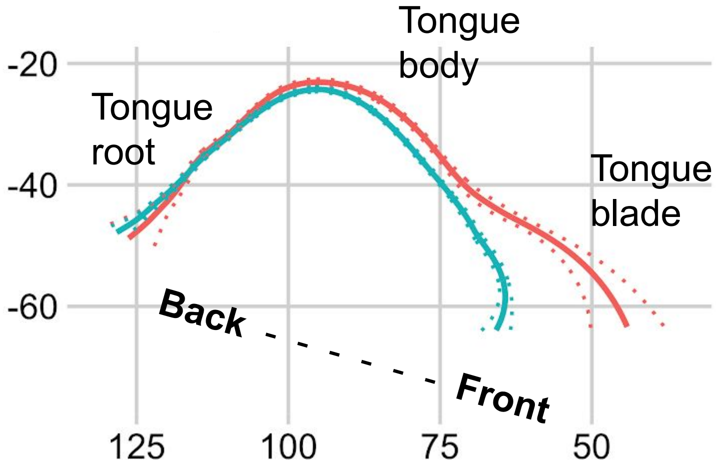
- Telemed Micro ultrasound device (83 frames per second)
- Held in place by an UltraFit stabilization headset (Spreafico et al. 2018)
- **Tongue surface contours** extracted using EdgeTrak (Li et al. 2005)

A sample of the moving tongue

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

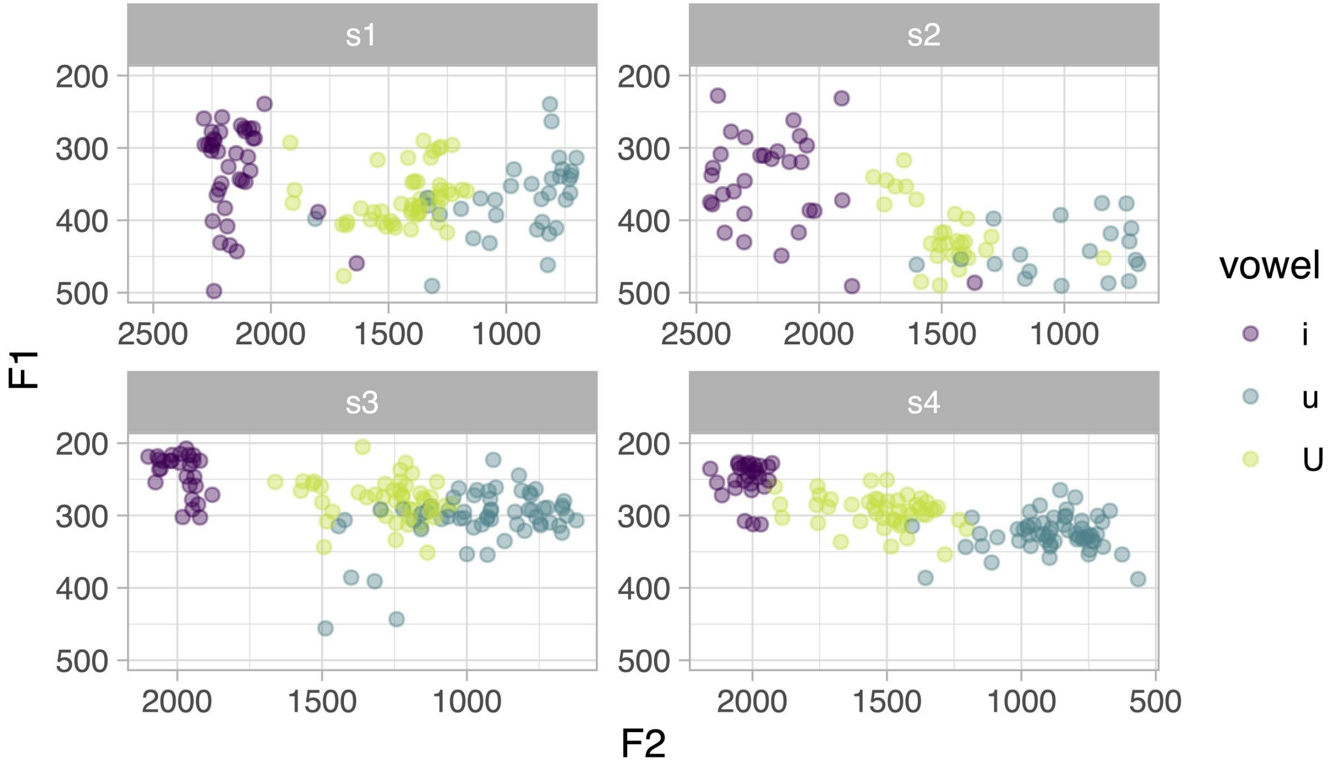
1. **Voicing:** active expansion entails
   - Tongue body lowering → **raised F1**
   - Tongue root advancement → **raised F2**

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

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

Prediction: Aspirated stops show lowered F1 and lowered F2 vs. unaspirated

Results: vowel F1, F2 by speaker



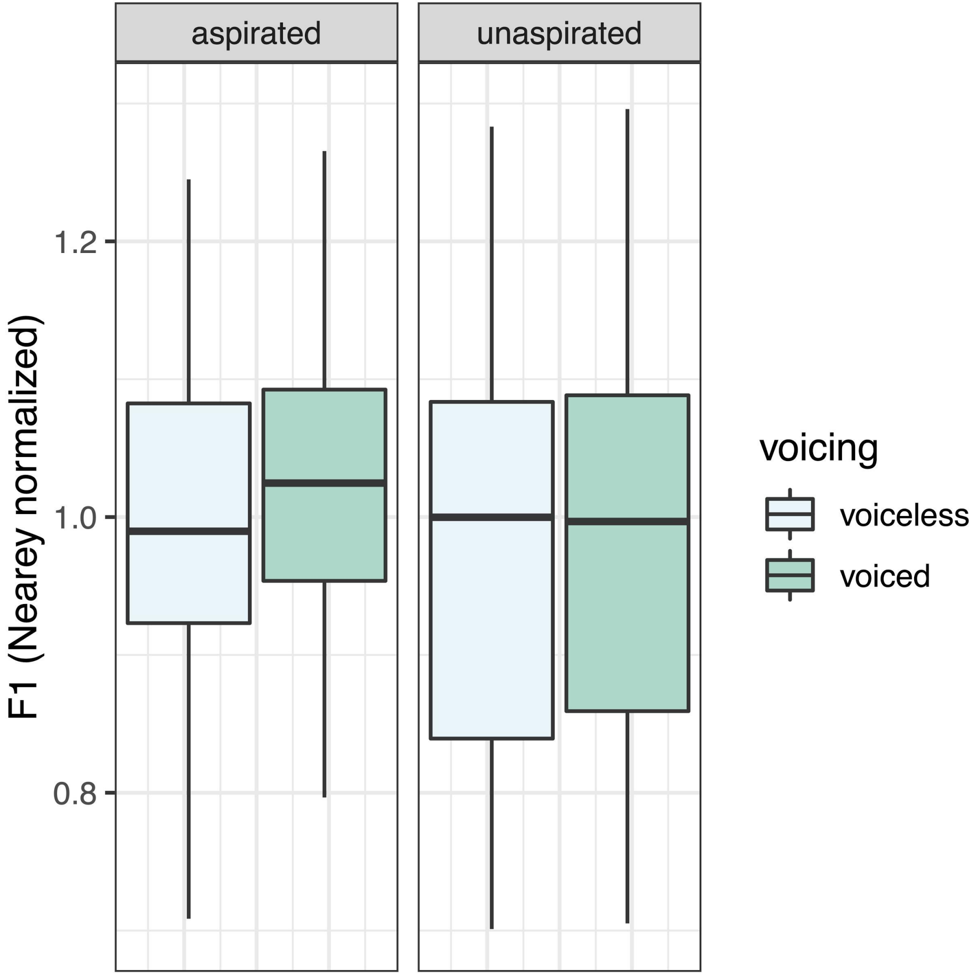
Results: F1 effects

Voicing credibly raises F1, though the effect is small (β=**26**, CI=[8,44])

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

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

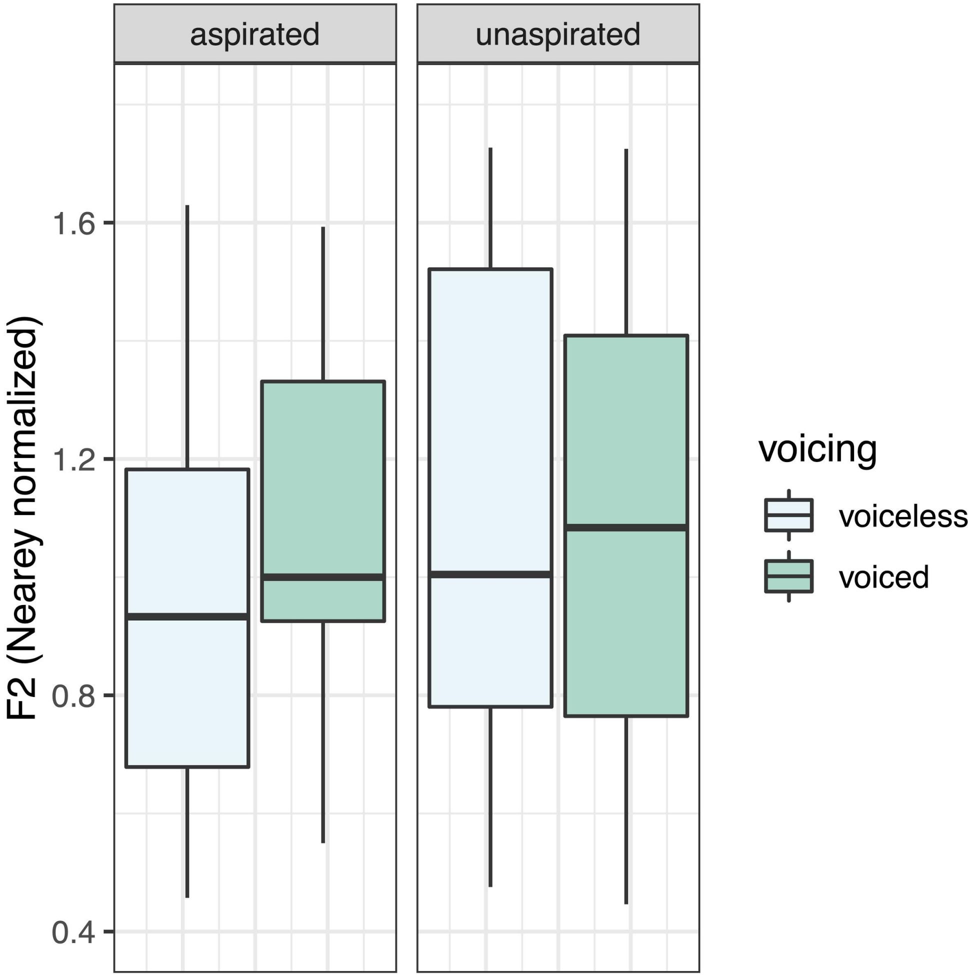
No effect of **aspiration** on F1 (β=**-3**, 95%CI=[-20,14])



Results: F2 effects

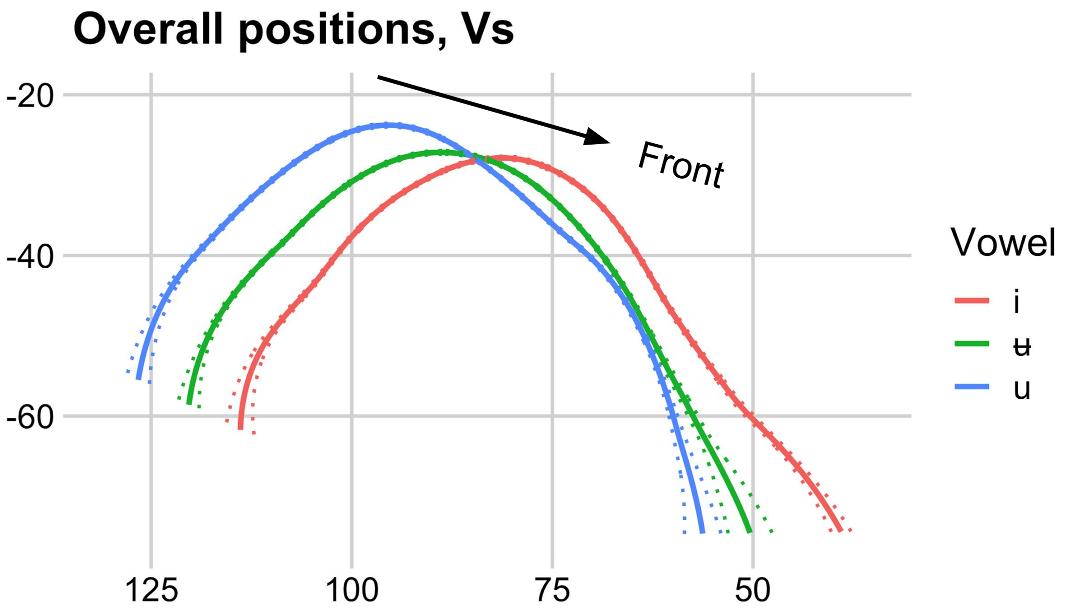
Voicing credibly raises F2
(β=**68**, CI=[25,110])

Aspiration credibly lowers F2
(β=**-64**, CI=[-104,-25])



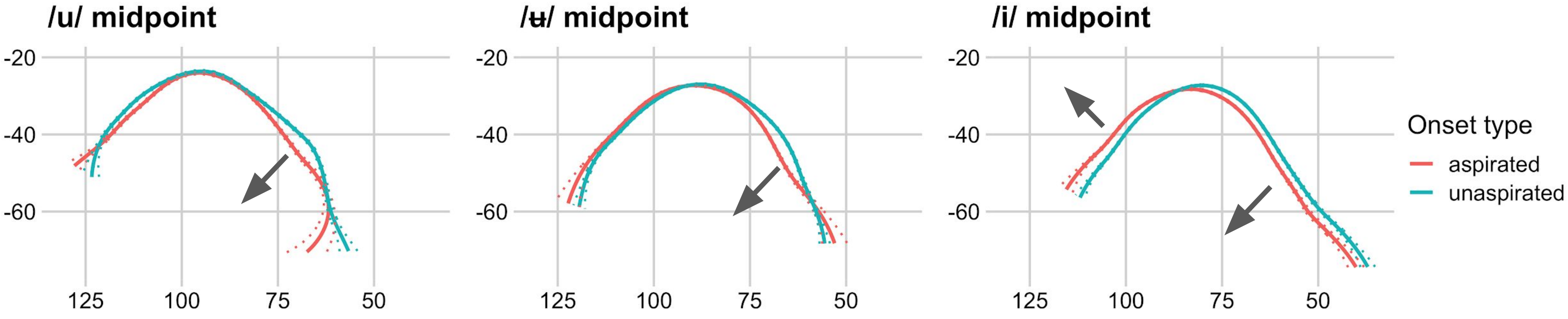
Results: ultrasound

Vowel differences reflected in the data as expected



Results: effect of aspiration

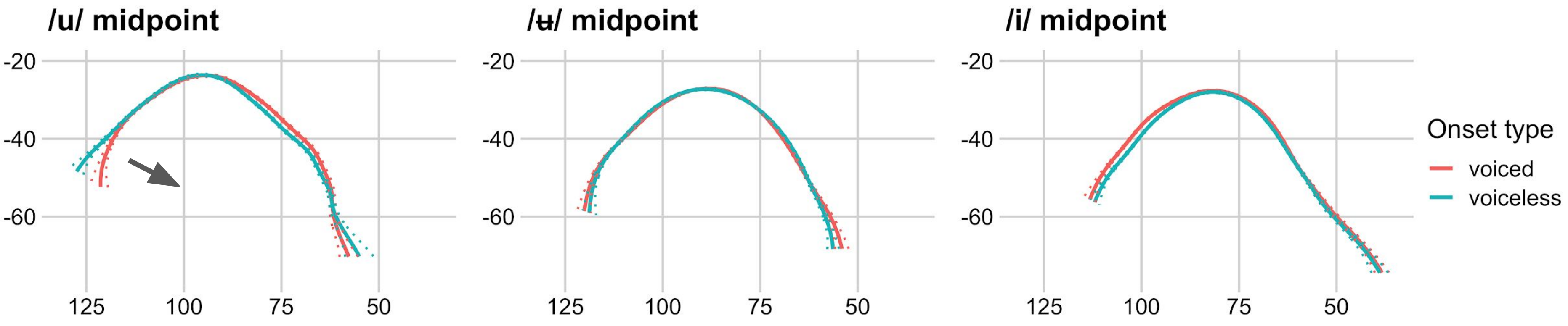
Presence of **aspiration** has a consistent effect: tongue root retraction and/or tongue body lowering



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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Appendix: vowels by speaker (Nearey normalized)