Effects of Aspiration and Voicing on Vowel Acoustics in Yemba

Jae Weller & Jeremy Steffman

Research Question

How do voicing and aspiration independently affect the supraglottal cavity, in a language where they vary orthogonally?

In this study - we use acoustic data (F1 & F2) to approximate these effects

Voicing, aspiration, and supralaryngeal articulation

Maintenance of voicing during stop closure reflected in tongue position

-Expansion of oral cavity helps sustain pressure gradient for voicing

Aspiration also thought to affect tongue position

-Possibly compression of oral cavity assists with burst of air for aspiration

The effects of voicing can be difficult to separate from aspiration, because in many languages voicing and aspiration do not vary independently

Voicing and aspiration in Yemba

Yemba is a Grassfields Bantu language spoken primarily in Cameroon
Voicing and aspiration vary independently (Bird 1999)
Four laryngeal categories for stops:

	aspirated	**unaspirated**
voiceless	[$^{n}t^{h}i$] ‘host’	[^{n}ti] ‘write’
voiced	[$^{n}d^{h}i$] ‘descendant’	[^{n}di] ‘sir’

The voiced aspirated stops are voiced stops followed by voiceless aspiration
This allows us to examine independent effects of voicing and aspiration

Methods

Corpus : Four speakers (3M, 1F)

- Two speakers were recorded at the UCLA Phonetics Lab (controlled materials)
- 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 X voicing)

Measurement: F1 and F2 measured at vowel midpoint

Analysis: Mixed effects Bayesian linear regression

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

Predictions: linking formants to effects

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**

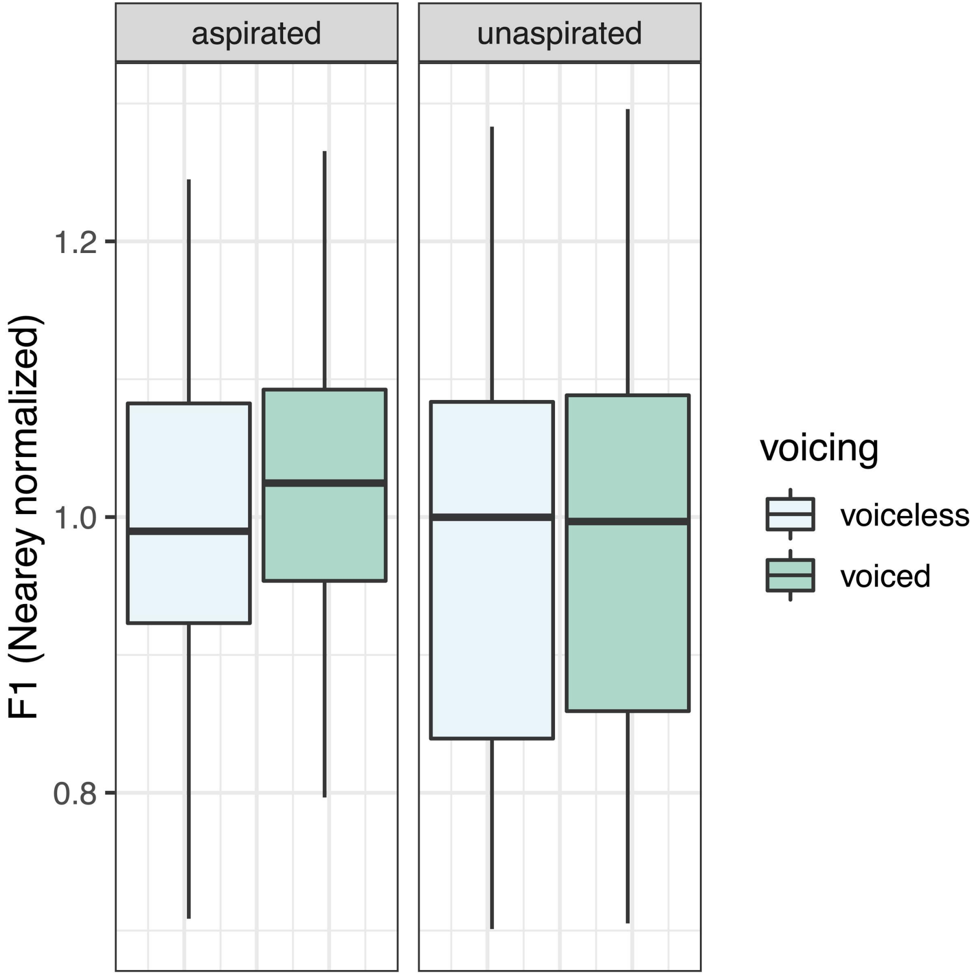
Prediction: Aspirated stops show raised F1 and raised F2 vs. unaspirated

Results: F1

Voicing credibly raises F1, though the effect is relatively small (β=26, 95%CI=[8,44])

Seemingly more influence for asp. stops -though no interaction observed

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

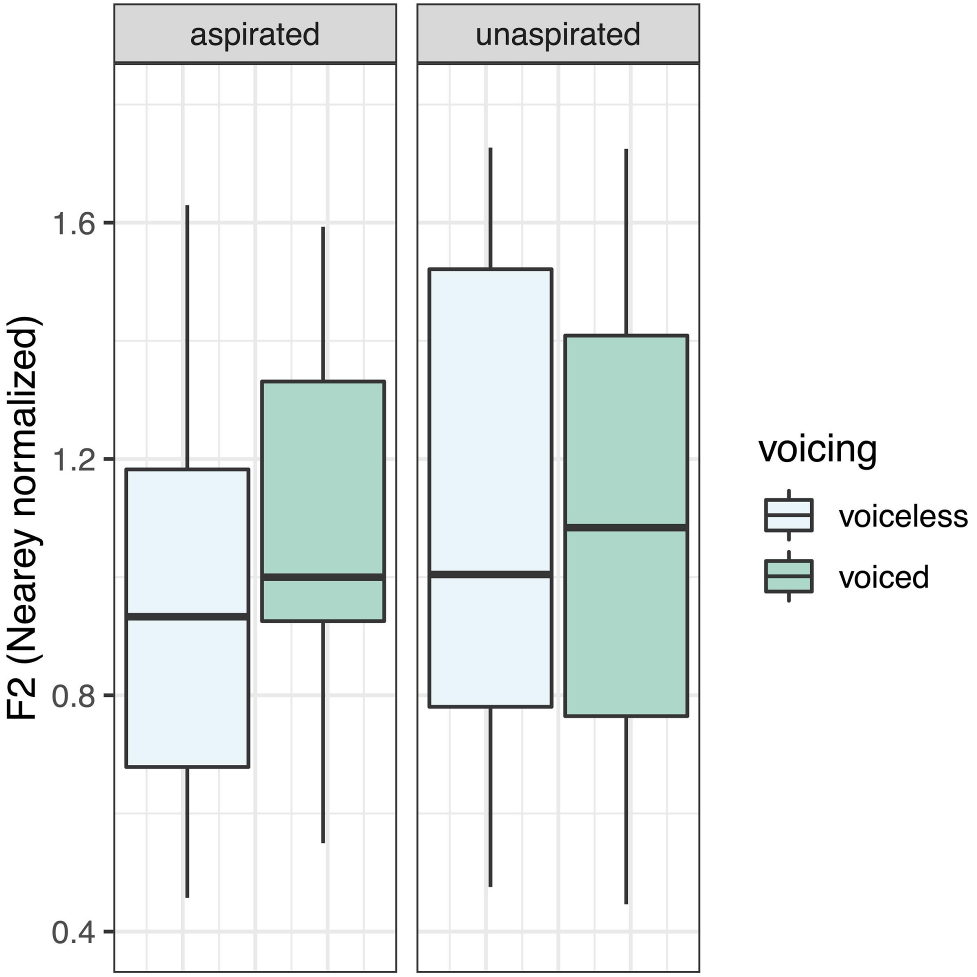


N.b. JND for F1 and F2 ≈ 20 Hz (Flanagan, 1955)

Results: F2

Voicing credibly raises F2
(β=68, 95%CI=[25,110])

Aspiration credibly lowers F2
(β=-64, 95%CI=[-104,-25])



Conclusions

-Results were mostly consistent with predictions

-Aspiration & voicing have small, independent effects on supraglottal cavity size

-Expansion for voiced stops, compression for aspirated stops

-Ultrasound data for one speaker will be incorporated soon!

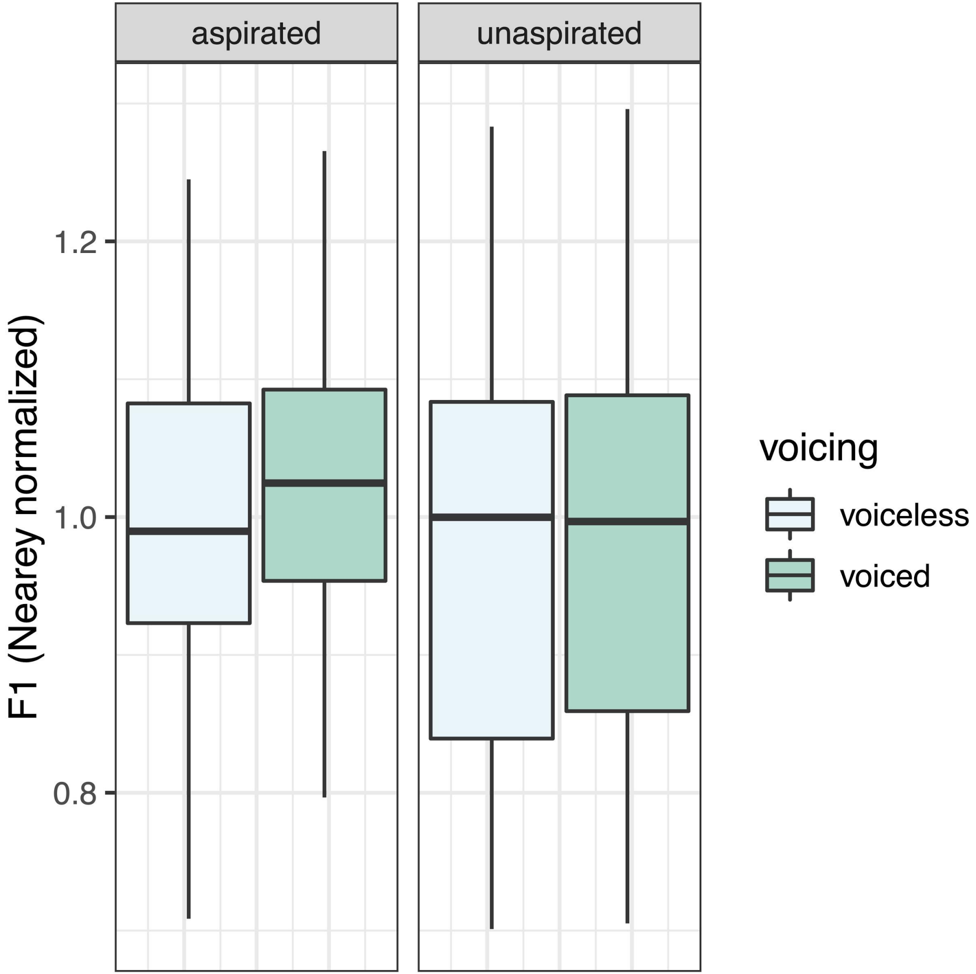
Thank you!

Results: F1 (Detail)

Voicing credible effect
(β=26, 95%CI=[8,44])

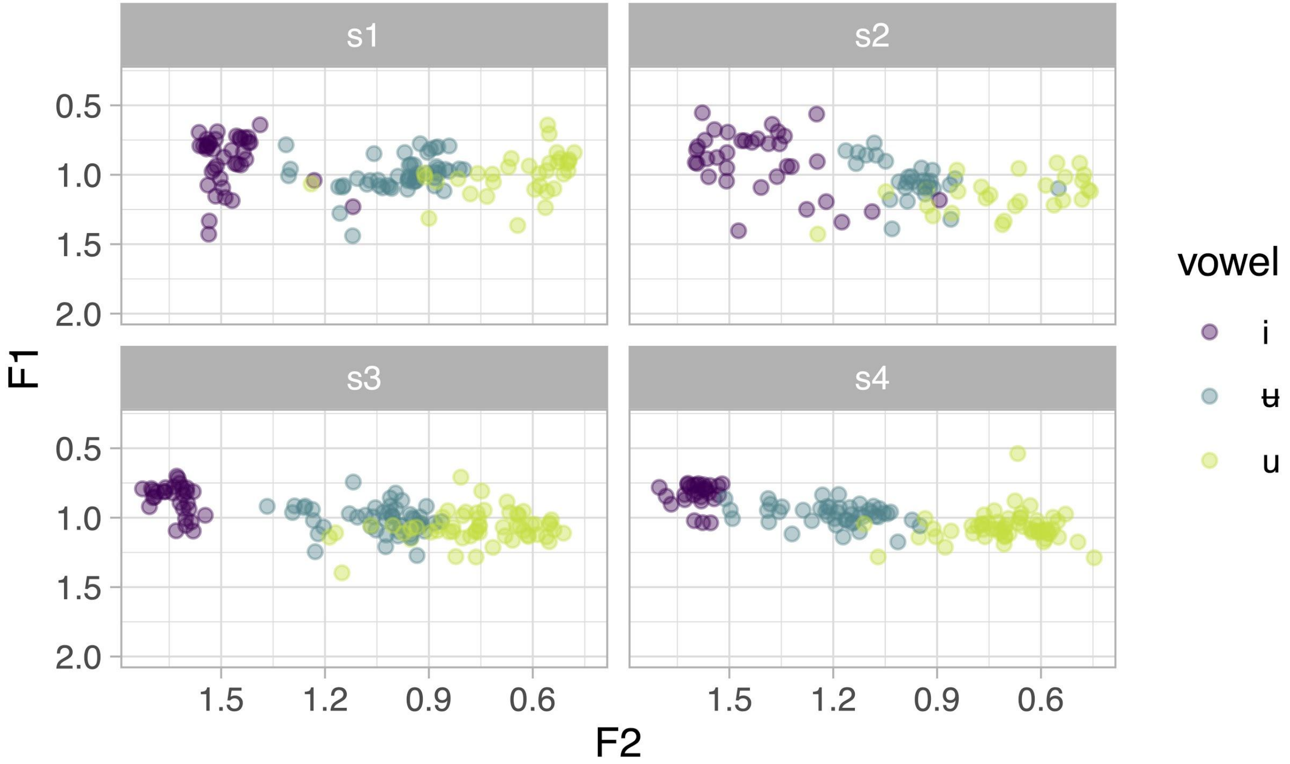
No interaction but model estimates a larger effect for aspirated sounds[1]

Aspirated: β=30, 95%CI=[2,57]
Unaspirated: β=21, 95%CI=[1,43]



[1] Calculated via emmeans (Lenth 2020)

Appendix: vowels by speaker (Nearey normalized)



Voicing Adjustments (In Detail)

Aerodynamic Voicing Constraint (AVC) (Ohala, 2011)

- -Voiced stops: voicing maintained during stop closure
- -A sufficient pressure gradient is needed across the glottis in order for air to make the vocal folds vibrate
- -There are a few possible adjustments to sustain the pressure gradient, including active expansion of the supraglottal cavity
    - -Found in English & Portugese (Westerbury, 1982; Ahn 2015 & 2018)

-English is unclear because of aspiration causing possible compression (also Ahn)

The effects of voicing can be difficult to separate from aspiration, because in many languages voicing and aspiration do not vary independently

Other Voicing Adjustments During Stop Closure

-Active expansion of the supraglottal cavity

- -Includes body tongue lowering and tongue root advancement, which this project examines
- -Also includes lowering of the larynx

-Passive expansion of the supraglottal cavity

- -Allowing outward motion of the cheeks for labial stops

-Incomplete closure of the velum

- -Air leaks out of the vocal tract while there is an oral stop

References

Ahn, S. (2018). The role of tongue position in laryngeal contrasts: An ultrasound study of English and Brazilian Portuguese. *Journal of Phonetics* 71.

Ahn, S. (2015). Tongue root contributions to voicing in utterance-initial stops in American English. In *Proceedings of Meetings on Acoustics* (Vol. 25, 060008).

Bird, S. (1999). Dschang syllable structure. In van der Hulst and Ritter (eds.), *The Syllable: Views and Facts*. New York: Mouton de Gruyter.

Bird, S. (2003). Grassfields Bantu Fieldwork: Dschang Lexicon. Linguistic Data Consortium.

Flanagan, J. L. (1955). A difference limen for vowel formant frequency. *The journal of the Acoustical Society of America*, *27*(3), 613-617.

Lenth, R. (2020). emmeans: Estimated Marginal Means, aka Least-Squares Means. R package version 1.5.3. https://CRAN.R-project.org/package=emmeans

Keating, P. (1984). Phonetic and phonological representation of stop consonant voicing. *Language* 60(2), 286-319.

Kent, R. D., & Moll, K. L. (1969). Vocal-tract characteristics of the stop cognates. *The Journal of the Acoustical Society of America* 46(6B), 1549–1555.

Ohala, J. (2011). Accommodation to the Aerodynamic Voicing Constraint and its Phonological Relevance. Proceedings of ICPhS 17*,* Hong Kong.

Ohala, J. (1983). The origin of sound patterns in vocal tract constraints. In MacNeilage, P. (ed.), *The production of speech*, 189-216. New York: Springer.

Rothenberg, M. (1968). *The breath-stream dynamics of simple-released-plosive production.* Basel: Karger.

Solé, M. (2018). Articulatory adjustments in initial voiced stops in Spanish, French and English. *Journal of Phonetics* 66, 217-214.

Westbury, J. (1982). Enlargement of the supraglottal cavity and its relation to stop consonant voicing. *The Journal of the Acoustical Society of America* 73, 1332-1336.