Enriching the Understanding of Glottalic Consonant Production: Vertical Larynx Movement in Hausa Ejectives and Implosives

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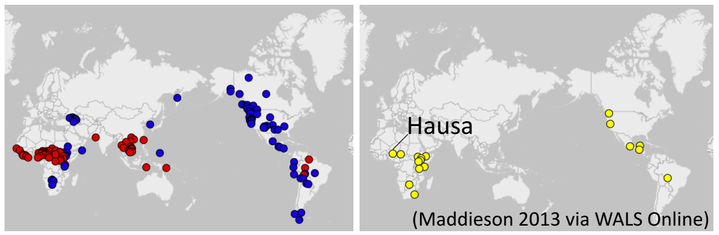
INTRODUCTION – GLOTTALIC CONSONANTS



● Implosives ● Ejectives ● Ejectives & Implosives

- Vertical aspects of the larynx movement (VLM) in glottalic consonants have rarely been studied.
- VLM is predicted to be larger in glottalic consonants than their pulmonic counterparts (Clements & Osu 2002, Kingston 1985, Ladefoged & Maddieson 1996).
- Due to their specific aerodynamic demands, gestures in glottalic consonants may be more tightly coordinated (stable) than gestures in pulmonic consonants.

Q How can we distinguish implosives from voiced pulmonics?
i) Degree of larynx lowering?
ii) Asynchronous coordination with its concurrent oral gesture?

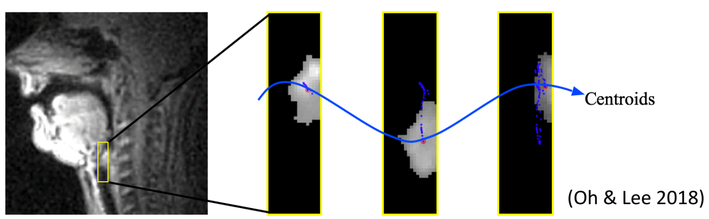
Q Is VLM in glottalic consonants phase-locked with oral closure to change air pressure?

METHOD

- **Real-time MRI** data produced by a female Hausa speaker
- Target consonants: word-initially in LH bi-syllabic words, /**C**aCV/

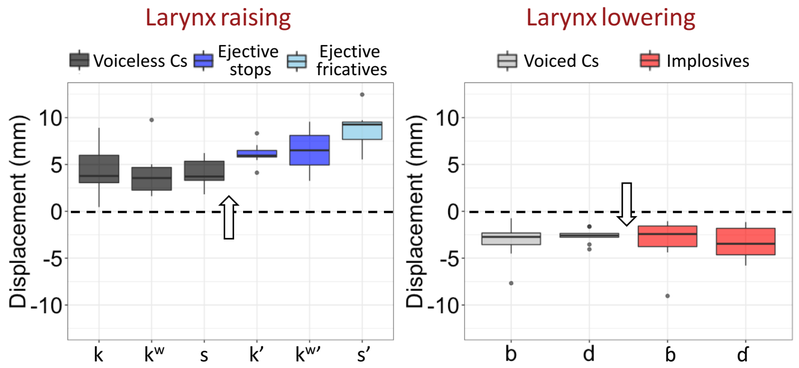
Implosives	Voiced pulmonics	Ejectives	Voiceless pulmonics
/ ɓ, ɗ /	/ b, d /	/ k', kʷ', s' /	/ k, kʷ, s /

- **Region-of-Interest (ROI) analysis** for oral constrictions
- **A centroid tracking tool** (Oh & Lee 2018) is used for VLM, which quantifies the centroids of the larynx in a given rectangular ROI for each time frame.



(Oh & Lee 2018)

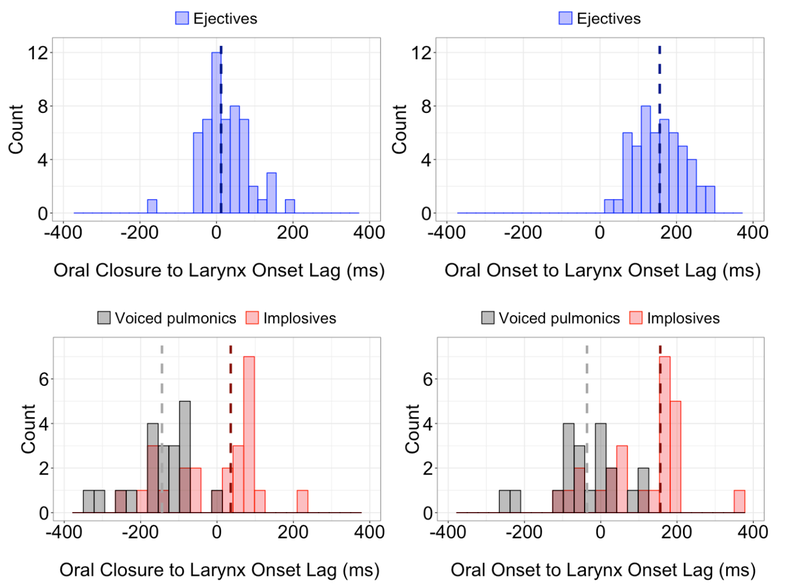
RESULT 1 - DISPLACEMENT



- Voiceless pulmonics < ejectives
- Voiced pulmonics ≈ implosives

→ No difference in VLM's magnitude between voiced stops and implosives

RESULT 2 – RELATIVE TIMING



- **Near zero** in ejectives & implosives
- **Negative lag** in voiced pulmonics
- **Near zero** in voiced pulmonics
- **Positive lag** in ejectives & implosives

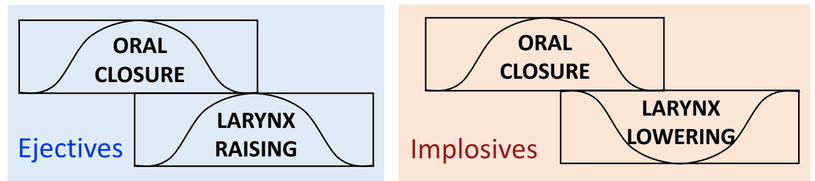
→ Synchronous production of oral constriction gesture and VLM in voiced pulmonics

→ VLM is more tightly coordinated with oral closure in ejectives and more variable in implosives

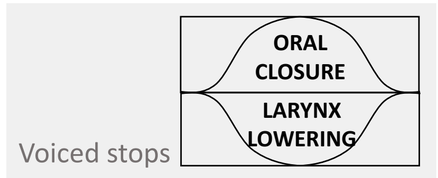
CONCLUSIONS

- VLM is found to be larger in ejectives than in voiceless consonants.
- Among ejectives, *ejective fricatives* show larger VLM than *ejective stops*, possibly due to maintaining sufficient airflow for turbulence.
- Contrary to the prediction, vertical larynx lowering is not larger in implosives compared to voiced stops.
- Difference between implosives and voiced stops is found in the lag between oral constriction gesture and VLM. Implosives exhibit larynx lowering at oral closure achievement, whereas voiced stops show simultaneous initiation of oral closure and larynx lowering.
- Based on the findings, we propose the following coordination structures for the glottalic consonants, extending coupled oscillator model of syllable structure (Goldstein et al. 2009) to gestures within a complex segment:

Glottalic consonants (anti-phase)



Pulmonic consonants (in-phase)



References

Clements, G. N., & Osu, S. (2002). Explosives, implosives and nonexplosives: the linguistic function of air pressure differences in stops. In C. Gussenhoven, & N. Warner (eds.), *Laboratory Phonology 7* (pp. 299-350). Berlin/New York: Mouton de Gruyter. **Goldstein, L., Nam, H., Saltzman, E., & Chitoran, I.** (2009). Coupled oscillator planning model of speech timing and syllable structure. *Frontiers in phonetics and speech science*, 239-250. **Kingston, J.** (1985). *The Phonetics and Phonology of the Timing of Oral and Glottal Events*. Doctoral dissertation. University of California, Berkeley. **Ladefoged, P., & Maddieson, I.** (1996). *The Sounds of the World's Languages*, Oxford: Basil. **Maddieson, I.** (2013). Glottalized Consonants. In: Dryer, Matthew S. & Haspelmath, Martin (eds.) *The World Atlas of Language Structures Online.* Leipzig: Max Planck Institute for Evolutionary Anthropology. **Oh, M., & Lee, Y.** (2018). ACT: An Automatic Centroid Tracking tool for analyzing vocal tract actions in real-time magnetic resonance imaging speech production data, *The Journal of the Acoustical Society of America, 114*(4), EL290-EL296.

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