Vertical larynx actions and larynx-oral timing in ejectives and implosives

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Goal

• Understand **the articulatory constellation** of ejectives and implosives in comparison with their pulmonic counterparts.

• Vertical larynx activity

• Timing of vertical larynx-oral gestures
Non-pulmonic vs. pulmonic consonants

• Manifested by the difference in “the mode of action of the larynx, or in the timing of laryngeal activity in relation to the oral articulation”

Maddieson & Ladefoged, 1996: 47

• Raising/lowering of the larynx

• Temporal coordination of oral-laryngeal activities

Ladefoged & Johnson, 2014
Implosives vs. voiced stops

• There is a gradient continuum between one form of voiced stops and true implosives
  • Implosives are produced with a comparatively greater amount of lowering and more rapid descent of the larynx than voiced stops.
    Ladefoged 1971, Ladefoged & Maddieson 1996

• Does the timing of larynx movement vary to create phonological contrasts?

  "Larynx is at its highest [for ejectives] or lowest [for implosives] point near the oral release, since maneuvers which change the volume of the oral cavity have more profound effects on [oral air pressure] if they are initiated after the oral closure is made."
  Kingston 1985: 17-18
Articulatory data

- Real-time MRI data of a midsagittal view of the vocal tract
Research Questions

A. Do ejectives and implosives show distinctive raising and lowering of the larynx (compared to pulmonic consonants)?

Hypothesis A

• **Non-pulmonic consonants** show larger and faster vertical larynx movement than their **pulmonic counterparts**.

  i. Voiceless pulmonics < **Voiceless ejectives**

  ii. Voiced pulmonics < **Voiced implosives**

**Research Questions**

B. What are the timing relations between vertical larynx gestures and their coordinated oral gestures?

**Hypothesis B**

i. The temporal lag between oral closure and vertical larynx gestures is near zero and **highly stable** in **ejectives** and longer and **more variable** in **implosives**.

ii. The temporal lag between oral and vertical larynx gestures in **voiced pulmonics** that exhibit larynx lowering is **more variable** than that seen in **non-pulmonic implosives**.

Ladefoged & Johnson, 2014
Methods

• **Subject:** A female Hausa speaker in 20s

• **Materials**
  - **Stimuli:** target consonant placed word-initially in LH bi-syllabic words
  - 2 prosodic conditions X 2 vowel contexts X 5 repetitions

<table>
<thead>
<tr>
<th></th>
<th>Bilabial</th>
<th>Alveolar</th>
<th>Velar</th>
<th>Labio-velar</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plosive</strong></td>
<td>b</td>
<td>d</td>
<td>k</td>
<td>k(^w)</td>
</tr>
<tr>
<td><strong>Implosive</strong></td>
<td>b</td>
<td>d</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ejective</strong></td>
<td></td>
<td>s'</td>
<td>k'</td>
<td>k(^w')</td>
</tr>
<tr>
<td><strong>Fricative</strong></td>
<td></td>
<td>s</td>
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Examples

• **Ejective**
  - Kaho ya na da wahalan busawa.
  - *Trumpet* is *difficult* to play.

• **Implosive**
  - Barna ya kawo kashe kudi.
  - *The loss* has led to spending *money.*
Data analysis

- Oral gestures (LAB, COR, DOR):
  - ROI analysis

- Vertical laryngeal gesture (LX):
  - Centroid tracking analysis
Larynx lowering (/ɑɡɑ/)
Larynx lowering (/ɑɡɑ/)
Measurements

• Magnitude
  ① Displacement (MAX-y – ONS-y)
  ② Peak velocity (PVEL)
  ③ Extremum (MAX-y)

ONS/OFF: onset/offset of the movement
PVEL: peak velocity
MAX: maximum displacement of the gesture
CLOSURE/RELEASE: target of oral closure/onset of oral release
Measurements

- **Timing**
  1. Oral closure
  2. Oral maximum to LX onset lag
  3. Oral release
  4. Onset to onset lag
Velar ejective (/k’/)

DOR

LX

1 2 3 4
Results (displacement)

Hypothesis A: Ejectives and implosives show larger and faster vertical larynx movement than their pulmonic counterparts.

![Graph showing larynx raising and lowering displacements for different categories of consonants.](image)

- **Larynx raising**
  - Voiceless Cs
  - Ejective stops
  - Ejective fricatives

- **Larynx lowering**
  - Voiced Cs
  - Implosives

Voiceless pulmonics < Ejectives
Voiced pulmonics ≈ Implosives
Results (Extremum)

Vertical larynx position at movement maximum (Extremum)
Results (Timing)

- Ejectives vs. Implosives

**Hypothesis B-i:** The temporal lag between oral and larynx gestures is near zero and highly stable in ejectives and longer and more variable in implosives.
**Results (Timing)**

- Hypothesis B-ii: The temporal lag between oral and larynx gestures in **voiced pulmonics** that exhibit larynx lowering is more variable than that seen in non-pulmonic implosives.

**• Implosives vs. Voiced stops**

<table>
<thead>
<tr>
<th>Oral closure to Larynx onset Lag</th>
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<td>Implosive</td>
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<td>Implosive</td>
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<th>Oral release to Larynx onset Lag</th>
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<td>Implosive</td>
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**Results (Timing)**

• Implosives vs. Voiced stops
Results (Timing)

- Ejectives
- Implosives
- Voiced stops

Near zero in ejectives & implosives
Negative lag in voiced pulmonics
Results (Timing)

- Ejectives
- Implosives
- Voiced stops

Near zero in voiced pulmonics
Positive lag in ejectives & implosives
Summary

A. Larynx actions

- Ejectives show **more upward** larynx movement than pulmonic consonants.
  - Ejective fricatives show **more upward** larynx movement than ejective stops.

B. Oral-vertical larynx timing

i. The timing between oral-larynx gestures is **less variable** in ejectives than in implosives.

ii. The timing between oral-larynx gestures is **more variable** in implosives than in voiced stops.
  - Larynx lowering is **synchronous** to oral constriction formation in voiced stops
    and **sequential** to oral gesture in implosives.
Conclusion

• Gestural organization of glottalic Cs

Glottalic consonants (anti-phase)

![Diagram of glottalic consonants (anti-phase)]

Pulmonic consonants (in-phase)

![Diagram of pulmonic consonants (in-phase)]
Conclusion

• Non-pulmonic consonants are in fact articulatorily distinct from pulmonic consonants, in the phasing between larynx-oral timing.

**Ejectives**
• Greater gestural magnitude (larynx raising), more stable timing, gestural sequencing

vs.

**Implosives**
• No magnitude difference (larynx lowering), more variable, gestural sequencing

**Voiced stops**
• larynx lowering, gestural synchrony
Future directions

• Collected three native Hausa speakers’ data with revised stimuli

• Prosodic variation: phrase-initial & phrase-medial
  • Influence of prosodic effects on the timing relations and gestural stiffness
    • Prosodic stability/variability
Acknowledgement
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