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

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Glottalic airstream consonants such as ejectives and implosives are produced by initiating airflow in the supralaryngeal vocal tract by means of changing vertical larynx position [1, 2, 3]. For instance, ejectives and implosives involve raising or lowering of the larynx, respectively, which can consequently increase/decrease supralaryngeal air pressure. Such vertical movement of the larynx is of course not unique to non-pulmonic consonants, as voicing, pitch changes, swallowing, etc. also involve changes in the vertical larynx position. While correlations of vertical larynx movement with tone and intraoral pressure are known, little articulatory data exists regarding vertical larynx action and its timing with oral constriction formation in non-pulmonic consonants. For example, no clear distinction has been identified in the articulatory actions responsible for the phonological contrast between voiced implosives and voiced pulmonic stops, as both permit larynx lowering to decrease oral air pressure and maintain voicing through oral cavity expansion [3, 4, 5].

This study examines vertical larynx movement in the production of Hausa ejectives and implosives as well as in their pulmonic counterparts, using real-time Magnetic Resonance Imaging (MRI) data at 83 frames/sec of the midsagittal vocal tract obtained from a native female Hausa speaker. The test consonants include ejectives (/k’, k^{w}’, s’/) and their pulmonic counterparts (/k, k^{w}, s/), as well as implosives (/ɓ, ɗ/) and voiced stops (/b, d/). These target consonants are placed word-initially in bi-syllabic words with a LH tonal pattern, followed by a vowel /ɑ/. Data acquisition followed a real-time MRI protocol developed and extended in [6, 7], and region-of-interest image sequence analysis [8] and novel centroid tracking [9] were used to extract kinematic trajectories of the articulators for spatiotemporal study.

Findings on the magnitude of vertical larynx movement indicate that among ejectives, ejective fricatives (/s’/) have greater maximal raising of the larynx compared to ejective stops (/k’, k^{w}’/) (Figure 1: left). This is possibly due to fricatives requiring the maintenance of sufficient air flow for turbulence. A contrast between voiced implosives and voiced stops in their degree of larynx lowering is not observed (Figure 1: right). The results on the relative timing between vertical larynx movement and the coordinated oral constriction are presented in Figure 2. In both ejectives and implosives, the temporal lag from oral closure to larynx onset (Figure 2 left) is near zero (dotted lines indicate the median), suggesting that the vertical larynx movement is closely coordinated with the oral closure achievement. In contrast, in voiced stops larynx lowering starts much earlier. When the lag between oral closure *onset* and larynx onset lag is examined (Figure 2 right), lags in voiced stops are variable, but centered around zero, indicating that the oral constriction formation and the larynx lowering start approximately simultaneously. In contrast, the strong positive onset-to-onset lags seen in glottalic consonants indicate that vertical larynx movements are initiated much later for both glottalic consonants.

In conclusion, the current findings suggest that implosives and voiced stops contrast in the relative timing of vertical larynx movement with respect to their coordinated oral closures, rather than differing in the magnitude of their larynx lowering. The findings are in line with phonetic descriptions of ejectives as characterized by increased oral air pressure, whereas implosives are better explained with the absence of any pressure increase [2, 4], though there may be no significant pressure decrease. Significantly, the observed coordination between vertical larynx movement and the oral closure can be analyzed in-phase coupling for pulmonic stops, but anti-phase coupling for glottalic consonants. This extends the coupled oscillator model of Goldstein et al. [10] to capturing contrasts in airstream mechanism via the organization of gestures within a complex segment. [Supported by NIH]

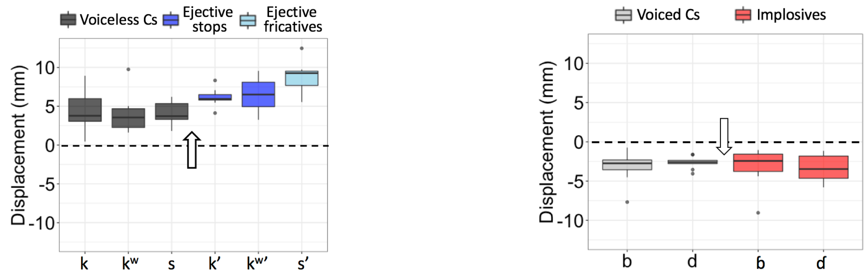

Figure 1. *Vertical larynx displacement*
(left: ejectives & voiceless consonants, right: implosives & voiced consonants)

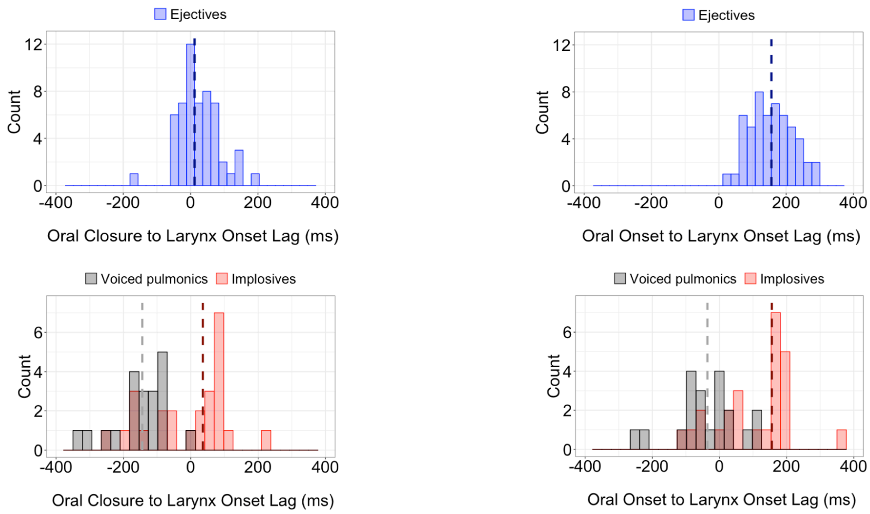

Figure 2. *Timing between oral gesture and vertical larynx movement*
(left: oral closure to larynx onset lag, right: oral onset to larynx onset lag)

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