Representations of Place and Airstream Mechanism: A real-time MRI study of Tigrinya ejectives
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Manner of articulation, including airstream mechanism, is not known to systematically affect place of articulation (cf. Hoole et. al., 1998). If such a systematic relation were identified, it could provide new ways of understanding how aerodynamics is integrated into the phonetic and phonological representation of speech sounds. However, there is currently little articulatory evidence of how the supralaryngeal vocal tract is configured in order to achieve particular airstreams, including glottalic egressives (ejectives). In this study, we use real-time magnetic resonance imaging (rtMRI; Fu et. al., 2015; Carignan et. al., 2015) to examine how the articulatory configurations associated with velar stops in Tigrinya are affected by pulmonic versus egressive airstreams.

The phonemic inventory of Tigrinya (South Semitic; Ethiopia and Eritrea) includes a set of ejective consonants contrastive with their voiceless, pulmonic counterparts. Ejectives are typically articulated by tightly adducting the vocal folds and raising the larynx, thereby increasing the supralaryngeal air pressure trapped in the cavity between the vocal folds and the oral constriction (Ladefoged, 1993). Upon the release of the oral constriction, “the entrapped high-pressure air will momentarily burst forth in a short sharp explosion” (Catford, 2001:22).

In this study, we use real-time magnetic resonance imaging (rtMRI; Fu et. al., 2015; Carignan et. al., 2015) to describe the articulatory configurations associated with the geminate, ejective and pulmonic, velar stops /kk’/-/kk/ in Tigrinya, and to describe the articulatory correlates of ejectivity above the larynx. Geminates were selected in this study because singleton velar stops in Tigrinya are subject to post-vocalic spirantization. Midsagittal images of the vocal tract were reconstructed at approximately 100 frames per second. Grayscale images were converted to black and white in order to calculate the (midsagittal) pharyngeal area. Time-varying pharyngeal areas were computed for the ejective and pulmonic members.

The rtMRI frame corresponding to the specific moment in time when the velar constriction is achieved is assumed to be the frame with the smallest pharyngeal area. Figure 1 below shows an example of this. The frame on the left corresponds to the smallest pharyngeal area in the several frames acquired throughout the duration of a single ejective /kk’/. The frame on the right is the same for a pulmonic /kk/. In both frames, a complete occlusion between the lingual articulator and the palate or soft palate is not visible, rather a thin narrow gap appears. Barlaz et. al. (2015) suggest that this may in part be due to the thin mucus membrane which covers the palatine bone and soft palate. This membrane is not registered in the rtMRI scans and thus leaves a thin black layer to appear in its place. In their images, Barlaz et. al. (2015) measure dorso-velic distances in what were known to be unspirantized velar stops and report a gap on the order of 6.82 mm. The concern of the study at hand is the configuration of the entire vocal tract, and the region of closest approximation between the articulators, rather than a particular point of contact.

In the ejective /kk’/, the MR images show retraction of the tongue root and dorsum along with forward expansion of the upper posterior pharyngeal wall; neither gesture is observed during pulmonic /kk/. Forward expansion of the upper posterior pharyngeal wall has been suggested to result from the raising of the larynx (Laradi, 1983:302 in Heselwood, 1996). Such a complex mechanism may not be necessary, however. Though the pharynx generally has little ability to dilate through contraction of its own musculature, the upper pharyngeal constrictor is indeed capable of independent dilation (Zemlin, 1997) and is evidently at work during the Tigrinya ejective. Tongue dorsum/root retraction and upper pharyngeal constriction clearly decrease the volume of the supralaryngeal cavity behind the oral constriction. We argue that these gestures are implicated in achieving the high pressure associated with glottalic egressives and that this results in clear place differences between pulmonic and ejective stops.

The target speech sounds were located in word-medial position after /a/ and before /i/ and were uttered multiple times in a carrier phrase. We observe that pulmonic /kk/ is articulated at a more forward, post-
palatal place of articulation than /kk’/, which may best be described as velar or post-velar. Pulmonic /kk/ is coarticulated with /i/, resulting in palatalized [kk’]. In contrast, ejective /kk’/ (also followed by a high front /i/) is articulated at a more posterior velar or post-velar place. We argue that this retraction in tongue body position serves to decrease the volume of the supralaryngeal cavity behind the oral constriction and thereby increases the air pressure behind the oral constriction, which is also built up by the rising larynx. These observations suggest that ejective /kk’/ is resistant to coarticulation and has a more posterior place of articulation.

While the results of this study describe a synchronic phonological process, they shed light on a possible diachronic process as well. Auditory similarities have been reported between Tigrinya ejectives and Arabic pharyngealized consonants (Fre Woldu, 1984-86). While it has been hypothesized that the pharyngealized consonants of Arabic evolved from Proto-Semitic ejectives (Heselwood, 1996 and Kogan, 2011), it has also been argued that the pharyngealized consonants were original to Proto-Semitic and that they came to be realized as ejectives in Ethio-Semitic due to Cushitic influence (Leslau, 1988). Thus, the articulatory representation of ejectivity in Tigrinya may help explain the articulation of pharyngealized consonants in Arabic.

**Figure 1**: midsagittal view of the articulatory configuration during /kk’/ (left) and /kk/ (right). During /k’/, a more constricted pharynx is observed during /k’/, as well as a more retracted tongue root, and more posterior oral constriction.

**References**


