Modeling the development of a new vowel feature: rhoticity in Kalasha

Jeff Mielke*, Qandeel Hussain* and Scott Moisik**
qhussai@ncsu.edu; jimielke@ncsu.edu; scott.moisik@ntu.edu.sg
*North Carolina State University, USA; **Nanyang Technological University, Singapore

Retroflex or rhotic vowels are found in fewer than 1% of the world's languages (Maddieson, 1984; Moran et al., 2014). While vowel rhoticity may be considered marginal from a broad crosslinguistic perspective, it is a basic vowel feature in Kalasha, an endangered Dardic (Indo-Aryan) language which contrasts plain oral (/i e a o u/), nasal (/ĩ ẽ ã õ ũ/), rhotic (/i˞ e˞ a˞ o˞ u˞/), and rhotic-nasal vowels (/ĩ˞ ẽ˞ ã˞ õ˞ ũ˞/) (Cooper, 2005; Kochetov et al., ms). We present an articulatory (and biomechanical modeling) investigation of Kalasha vowels and the vowel-liquid sequences of neighboring Dardic and Nuristani languages (Dameli, Kati, and Kami). Since the vowel system of Kalasha appears to have developed rhoticity fairly recently (Heegård & Mørch, 2004), it provides an opportunity to explore the development of a typologically marked vowel feature.

Fifteen speakers were recorded in Bumburate valley (Chitral) and Peshawar, Pakistan (Kalasha: 4 speakers; Dameli: 5 speakers; Kati: 3 speakers; Kami: 3 speakers). Simultaneous audio (44.1 kHz), ultrasound video (60 fps), and lip video (30 fps) data were collected. We find that Kalasha rhotic vowels are produced with the double-bunched tongue shape characteristic of bunched [ɹ] rather than retroflexion, and they are monophthongal rather than vowel-liquid sequences. The very low F3 which characterizes Kalasha rhotic vowels (Hussain & Mielke, 2019; Kochetov et al., ms) can be accounted for by the large space in front of the retracted tongue blade, consistent with the articulation of English bunched /ɹ/ (Mielke et al., 2016), as well as strictures at velocity antinodes. The lip rounding of the rhotic vowels is nearly identical to their non-rhotic counterparts (Figure 1), but the tongue shapes differ considerably within rhotic and non-rhotic pairs (Figure 2). While Kalasha rhotic vowels are produced with tongue bunching, it seems very likely that rhoticity originated due to the presence of retroflexion. Kalasha has rhotic vowels in words where they were historically followed by retroflex consonants (e.g., Old Indo-Aryan *paɳi 'hand' → Kalasha /pẽ˞/ 'palm of the hand') and also in words where neighboring Nuristani languages have vowel-rhotic approximant sequences (e.g., Kati /kuːɻ/ vs. Kalasha /kʰu˞/ 'hat'; Heegård & Mørch, 2004). Figure 3 compares the articulation of [a˞] ∼ [aɻ] in four languages: Kalasha has monophthongal bunched [a˞], while Kati and Kami (Nuristani) predominantly show much larger differences between the vowel and rhotic approximant tongue shapes, and a high tongue blade angle.

It is clear that the development of rhotic vowels out of plain vowel+retroflex sequences has involved substantial reorganization, including the switch from retroflexion to bunching and the extension of rhoticity across the entire vowel interval. To explore the acoustic and articulatory reorganization of the Kalasha vowel system we are now developing a series of simulations in ArtiSynth (Lloyd et al. 2012). We adapted Moisik & Dediu's (2017) simulation and integrated Birkholz's (2005) one-dimensional acoustic simulation. Ultrasound data of vowels produced by Kalasha speakers were used to drive the inverse model (Stavness et al., 2011) to reproduce the associated tongue shapes and generate a matching acoustic signal (see Figure 4). This biomechanical and acoustic modeling will enable us to describe in much more detail how the Kalasha vowel system has incorporated rhoticity (by comparing the acoustic output of observed tongue shapes with the acoustic output of the corresponding plain vowels overlapped with a tongue bunching gesture). It is already apparent that further reorganization has occurred: for instance, the rhotic mid vowels [e˞] and [o˞] differ from each other only in tongue root position and lip rounding (Figure 2), an unlikely result of adding tongue bunching to the plain counterparts of these vowels.

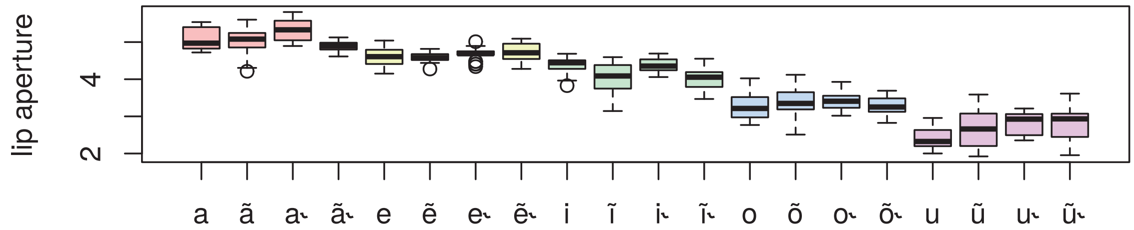

Figure 1: Lip aperture (measured between the left and right corners of the lips)

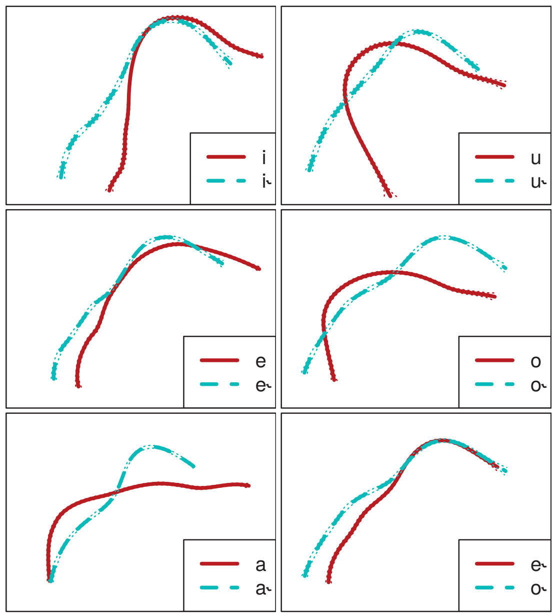

Figure 2: SSANOVA comparisons of five Kalasha plain-rhotic vowels plus the similar [e˞]-[o˞] pair. Tongue tip is on the right.

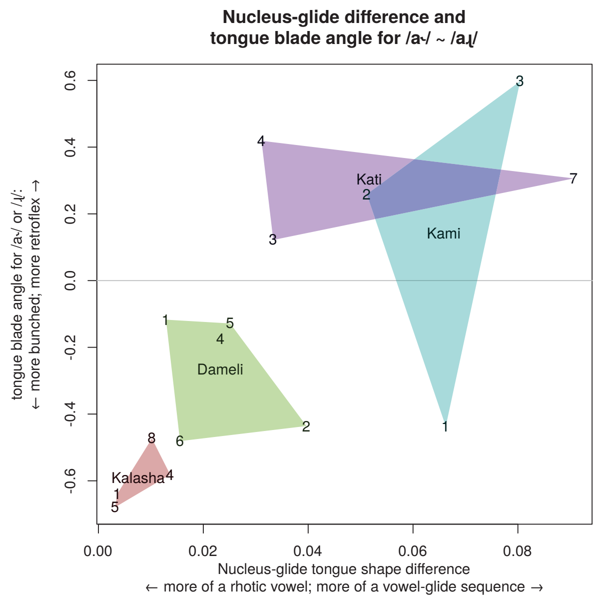

Figure 3: Differences in tongue blade angle (y-axis) and nucleus-glide tongue shape (x-axis) across four languages (Dardic: Dameli and Kalasha; Nuristani: Kati and Kami). Numbers represent speakers.

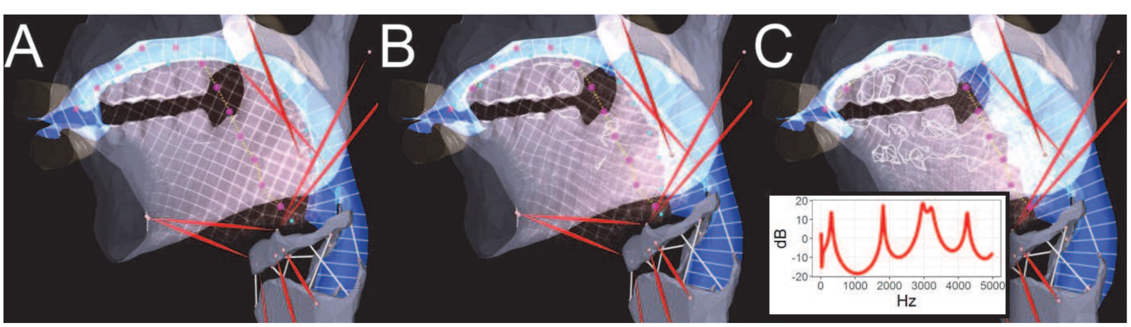

Figure 4: Three frames (A = start, B = middle, C = end) showing the process of registering the biomechanical tongue model to a lingual ultrasound trace of a Kalasha /i/ vowel (magenta dots) using the inverse model. The inlay in C shows the output spectrum.