Malayalam three-way rhotics contrast: Articulatory modelling based on MRI data

Alexei Kochetov[1,2], Christophe Savariaux[2], Laurent Lamalle[3], Camille Noûs[4], Pierre Badin[2]
[1] University of Toronto, [2] Univ. Grenoble Alpes, CNRS, Grenoble INP, [3]Inserm US 17, CNRS, Univ. Grenoble Alpes & CHU de Grenoble, [4] Cogitamus laboratory

Rhotic consonants have been of great interest to speech production, given their different phonetic types (taps, trills, approximants; alveolars, retroflexes, uvulars) and considerable variation across and within languages (e.g. [1, 2, 3, 4, 5]). With a few notable exceptions ([4, 5]), previous studies have focused on relatively simple rhotic inventories, containing one or two consonants. In this paper, we provide static MRI data on a 3-way rhotic contrast in Malayalam (Dravidian), consisting of an alveolar tap, an alveolar trill, and a retroflex approximant (e.g. /kaɾi/ 'soot', /kari/ 'curry', /kaɻi/ 'eat' [6]). The goal of this work is to shed light on the articulatory parameters underlying this complex and typologically rare contrast.

Single slice mid-sagittal MRI static images were recorded for two native speakers of Malayalam (1 female, SV; 1 male, BB) with a Philips Achieva 3.0T dStream scanner using a 20 channel head-neck coil in Turbo Spin Echo mode. The rhotics were produced in 5 symmetric V_V contexts (/a i u e o/), as part of a larger corpus containing a full set of consonant places and manners (22 phonemes). Semi-automatic segmentation of the main speech articulators from the MRI images was performed according to [7]. The contours were aligned with the hard palate, and used for comparisons of mean articulations and for performing articulatory modelling. The latter used the method in [8] to determine a small set of components (e.g. tongue tip fronting, tongue body raising, velum lowering, etc.) responsible for the implementation of various articulations. Values for each component were z-scored and plotted using radar charts. These two methods are illustrated in Figure 1, which shows overlaid average contours for the rhotics by SV (on the left) and the corresponding parameter values (on the right).

The results of our analysis revealed that, for both speakers, the tap and the trill were produced with the tongue tip against the alveolar ridge or slightly behind it (see Figure 1, left, for SV). This was fully expected, given previous descriptions of the sounds ([6]). The two consonants, however, were consistently differentiated by several parameters (see Figure 1, right, for SV): the tongue tip fronting (somewhat more advanced for /r/), the jaw height (slightly higher for /ɾ/), the hyoid bone raising (higher for /r/), and the tongue dorsum arching (considerably greater for /r/). The latter parameter is of particular interest, as it shows that the two consonants are differentiated by a secondary articulation (cf. [5, 6]), notably the velarization of the trill.

While exhibiting similar results for alveolar rhotics, the speakers differed strikingly in how they produced the approximant. SV produced /ɻ/ with the tongue tip mildly curled towards the hard palate (i.e. retroflex), while BB produced it with a strongly bunched front portion of the tongue articulating against the front portion of the palate. Both speakers differentiated the approximant from the tap and/or the trill by the tongue tip fronting (more retracted for /ɻ/), the larynx height (lower for /ɻ/), the hyoid fronting (more advanced for /ɻ/), and lip protrusions (greater for /ɻ/). In addition, the speakers made use of the tongue tip height, tongue body raising, and tongue dorsum arching, although in different directions (with greater values for /ɻ/ by BB and lower values by SV).

Altogether, the results show that the production of rhotic contrasts in Malayalam is fairly complex, consisting of primary and secondary constrictions, and involving multiple articulators. Moreover, even a small sample of two speakers revealed substantial differences in the tongue shapes used for the retroflex approximant, reminiscent of the variation observed for the English /ɹ/ ([1, 3]). This study provides a first step towards a more systematic articulatory characterization of complex lingual contrasts in Malayalam, and by this contributes to uncovering physiological bases of phonetic distinctive features and typological variation in rhotics.

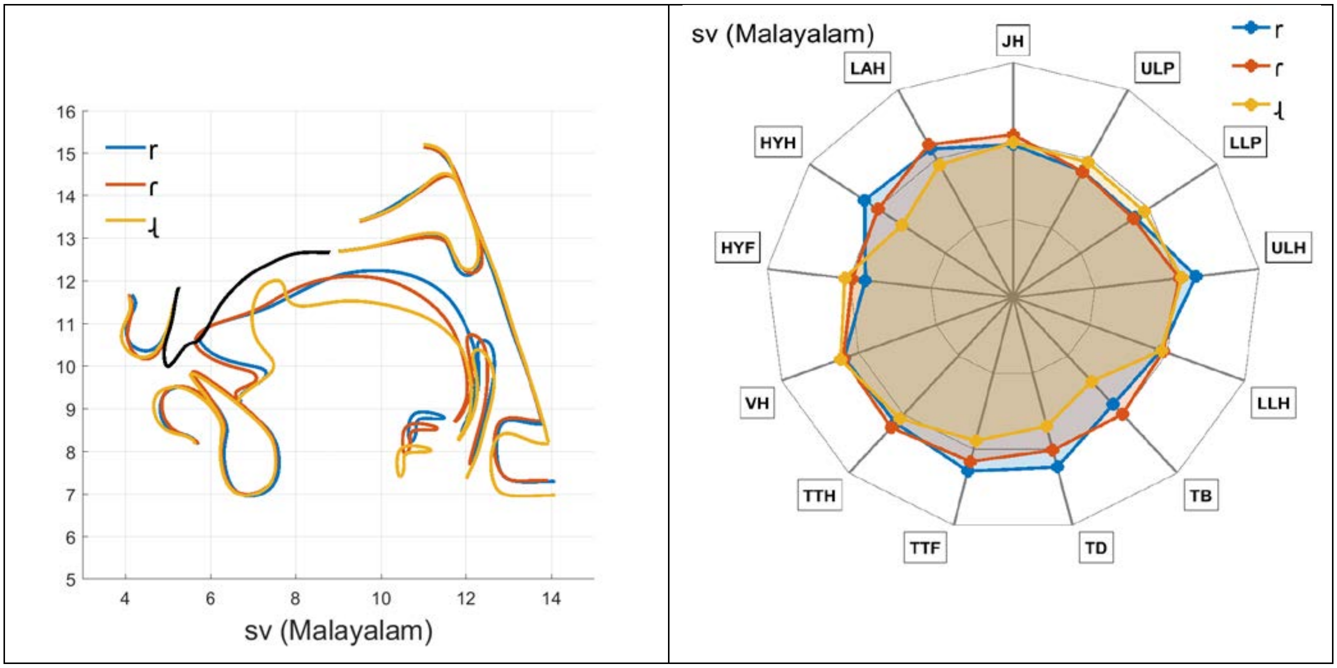

Figure 1. Overlaid contours averaged over 5 vowel contexts (left) and radar displays of z-scored articulatory parameter values (right) for the alveolar trill, alveolar tap, and retroflex approximant by speaker SV. The parameters are (clockwise): jaw height, upper lip protrusion, lower lip protrusion, upper lip height, lower lip height, tongue body, tongue dorsum, tongue tip fronting, tongue tip height, velum height, hyoid fronting, hyoid height, and laryngeal articulator. Values increase towards the outer polygon.

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