# ANALYSIS OF TONGUE SHAPES DURING THE PRODUCTION OF KANNADA CONSONANTS

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## 1. INTRODUCTION

Like many languages of South Asia, Kannada (Dravidian) exhibits a relatively complex set of lingual consonants that differ in place of articulation – dental, retroflex, alveolopalatal, and velar. Among these, retroflex consonants are particularly interesting, being produced with the tongue tip curled behind the alveolar ridge towards the hard palate. While a number of articulatory studies have examined retroflexes in South Asian languages (e.g. Švarný & Zvelebil, 1955; Narayanan *et al.*, 1999), few have systematically compared them to other lingual articulations. Moreover, there has been hardly any articulatory work on Kannada, in contrast to studies of consonants in other Dravidian languages such as Tamil and Telugu. The goal of this paper is to examine how the tongue shape for Kannada retroflex stop /T/ (IPA /ʈ/) differs from the shapes for alveolopalatal affricate /c/ (/ʧ/), dental stop /t/, and velar stop /k/. The data come from our earlier ultrasound study of Kannada lingual consonants produced by 4 native speakers of the language (Kochetov, Sreedevi, & Kasim, to appear). The focus of that study was on the relative displacement of the tongue in the production of these consonants, calculated as the difference between the tongue shapes during the consonant closure and the rest position. It was found that the retroflex stop and the palatal affricate were characterized by greater displacement compared to the dental and velar stops, suggestive of the greater articulatory complexity of the former two.

What was not directly investigated in that study is how exactly the retroflex tongue shapes differ from those of other places of articulation or from the rest position. That is, do the differences involve the entire tongue contour or only part of it (e.g. the tongue front or the anterior tongue body)? This question is important in light of the controversy about the role of the tongue body in retroflex articulations. Some researchers have proposed that retroflexion is accompanied by the tongue body backing – velarization or pharyngealization, which is either optional (Bhat, 1974) or obligatory (Hamann, 2003). This was predicted largely on phonological grounds, as backing in retroflexes would account for their cross-linguistic patterning with back vowels. Other researchers, based on some articulatory data, have argued that retroflexes require the tongue body 'bracing' or stabilization – to facilitate the palatal constriction and the characteristic forward movement of the tongue tip (Narayanan *et al.*, 1999; Best *et al.*, 2010). In the current study we address this question by performing statistical analyses of pairs of consonant tongue shapes, with the goal to determine to whether they differ in specific regions of the tongue, and in which direction.

## 2. METHOD

As mentioned earlier, the study used ultrasound data from Kochetov *et al.* (to appear), where 2 female (F1, F2) and 2 male speakers (M1, M2) produced 6 repetitions of the following Kannada words: /aTTa/ 'garret', /acca/ 'pure', /atta/ 'that side', and /akka/ 'elder sister'. Geminate consonants were used to obtain the duration adequate for the analysis (given the 15 frames per second rate of the system). The data were recorded using a PI 7.5 MHz *SeeMore* ultrasound probe by *Interson*, connected through a USB port to a laptop computer and captured by a DVD recorder. Video frames were selected for a number of time points, and tongue contours were traced using *EdgeTrak* (Li *et al.*, 2005). Each traced contour was saved as a set of 100 X and Y points. Figure 1 plots the resulting contours for 6 tokens of each of the 4 consonants (taken during the closure) produced by one of the speakers (M1). The front of the tongue is on the right. Note that ultrasound does not usually capture the tongue tip proper, and particularly when it is curled back (as for /T/). It is clear from the figure that there is considerable variation within each consonant category, while there are also differences among the consonants.

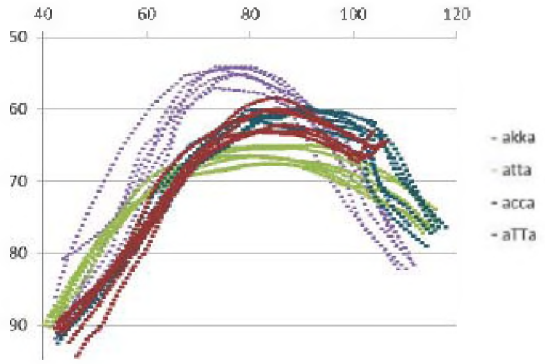


**Figure 1. Traced tongue contours (in mm) for consonants produced by speaker M1 (6 tokens per consonant).**

These differences were evaluated using a series of Smoothing Spline Analyses of Variance (SS-ANOVAs), the method that compares smoothing splines for two datasets and determines whether they are significantly different from each other (see Davidson, 2006 for details). The two curves are considered significantly different in a given region if their 95% confidence intervals do not overlap. For the purposes of the analysis, the tongue contour was divided into 3 regions – the posterior and anterior tongue body, and the tongue front (the blade and the tip, if visible). The input to the analysis were X and Y points for the most extreme tongue position during the consonant closure (point 0) for

pairs of words with retroflex /T/ (/aTTa/) and the other consonants (/acca/, /akka/, /atta/). In addition, a comparison was made between point 0 and the point at 10 frames prior to it (-10; or 333 ms before) for /aTTa/, which corresponded to the neutral position of the tongue (the rest position). The analysis was performed using the *assist* package of the *R* programming language (version R 2.14.1; www.r-project.org/). Overall, four SS-ANOVAs were run for each participant, with six tokens for each consonant, and each token being based on 100 X and Y data points.

## 3. RESULTS

Figure 2 presents the output of SS-ANOVAs for one of the speakers, M1. It can be seen in the upper left image that the curves for retroflex /T/ and alveolopalatal /c/ are almost identical in the posterior and part of the anterior tongue body regions (the leftmost 2/3). The difference between the two is mostly in the tongue front, which is raised for /T/ (and partly invisible due to the sound wave refraction) and lowered for /c/. Compared to velar /k/ (upper right), the entire tongue for /T/ is considerably fronted, with the anterior tongue body being in a lower position. The posterior tongue body fronting for /T/ is also notable when compared to dental /t/ (lower left), which has an overall lower and more stretched tongue shape. Finally, compared to the rest position, /T/ shows considerable fronting of the tongue body, and raising of it anterior part, together with the tongue front (which is presumably curled back).

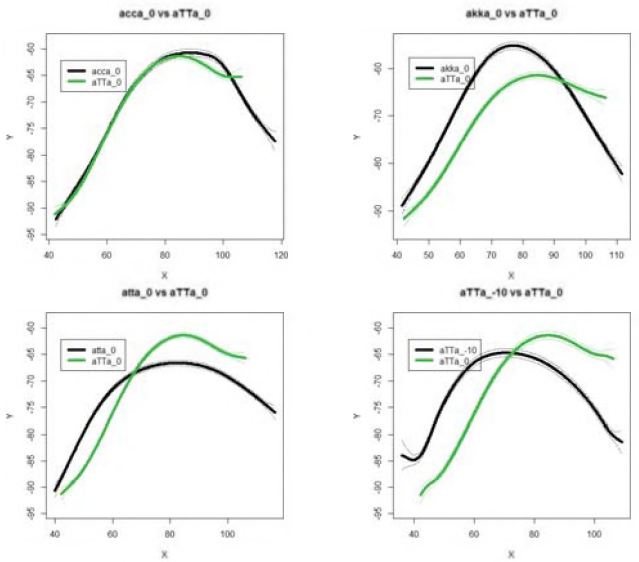


**Figure 2. Results of SS-ANOVA for 4 pairs of tongue contours (in mm) based on the data in Figure 1 (speaker M1).**

The results for the other speakers were overall similar. Specifically, the retroflex posterior tongue body was more front than for /k/ and the rest position, and similar to /c/. The anterior tongue body for /T/ was lower than for /k/, but higher than for /t/ and the rest position, and either slightly lower or higher than for /c/. The tongue front for /T/ was substantially higher than for the other articulations, except for /c/. In general, the retroflex and the alveolopalatal were most similar in terms of their tongue shapes, differing primarily in the direction of the tongue tip – up or down.

## 4. DISCUSSION AND CONCLUSION

The results of the statistical comparison of tongue shapes for Kannada lingual consonants are parallel to our earlier findings of displacement differences based on the same data. Posterior coronals, /T/ and /c/, have similar tongue body shapes and involve the greatest displacement from the rest position. The finding of the tongue body fronting for the retroflex stop, however, is unexpected given the prediction that the curling of the tongue tip should involve backing of the tongue body (Bhat, 1974; Hamann, 2003). More research is necessary to determine whether the results are representative of Kannada retroflex articulations in general. Yet, this finding appears to be compatible with earlier X-ray and MRI results for Tamil (Švarný & Zvelebil, 1955; Narayanan *et al.,* 1999), which found that the pharyngeal cavity was wider for retroflexes (and hence the more front tongue body) than for dentals or the rest position. At the very least, this suggests that the tongue body backing is not an obligatory property of retroflexion. In fact, the articulator can move in the opposite direction, likely as part of the stabilization phase facilitating the formation of the tip-up constriction and the subsequent tip forward movement, which is consistent with the observations made by Narayanan *et al.* (1999) and Best *et al.* (2010).

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