COMPARISON OF TONGUE CONTOURS IN CHILDREN AND ADULTS: A PRELIMINARY ULTRASOUND STUDY

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Ultrasound is a safe and non-invasive articulatory technique which tracks the shape of the tongue contours during the production of lingual sounds. Though ultrasound based studies are abundant in European languages, there are dearth of such studies in Indian languages. Kochetov et al (2012) studied lingual stops using ultrasound in native Kannada speaking adults and the results showed distinct tongue shapes for retroflex, dentals, and velars. They also reported that the retroflex consonants were predominantly sub-apical but the tongue body retraction is not an obligatory property of retroflexion. In this perspective, the present study is planned to compare the tongue contours for lingual stops across native Kannada speaking children and adults using ultrasound imaging. A total number of 20 subjects with equal number of children (9-10 years) and adults (23-25 years) participated in the study. The test material were three meaningful Kannada words; /atta/, /aTTa/ and /akka/ incorporating the dental /t/, retroflex/ ʈ / and velar /k/. For recording the sample, the transducer probe of the Mindray ultrasound 6600 was placed beneath the participant's chin. The software Articulate Assistant Advanced (AAA) ultrasound module (Version 2.14) was used for analysis. Smooth Spline Analysis of Variance (SS-ANOVA) was used to obtain the difference in the tongue contours. The results showed that tongue contours of children and adults are of similar patterns for the three places of articulation studied, but the overall height of the tongue contour is more in adults especially for the anterior tongue body region. The angle of retroflection was not prominent in both groups which reveal that retroflex sound production is not always sub-apical. This study augments our understanding about the similarities and differences in tongue dynamics across children and adults and it paves the way to understand better tongue dynamics in communication disordered population.

Key words: *Ultrasound, non-invasive, midsagittal tongue contour, Articulate Assistant Advanced, Smooth Spline Analysis of Variance.*

Introduction

Ultrasound is one of the imaging techniques to study the tongue movements during speech production. The configuration of an internal articulator like the tongue influences the acoustic characteristics of the sounds produced during speech production. Ultrasound is a safe and non-invasive articulatory technique, and it provides information about the shape of the midsagittal tongue contour, including the root (Stone, 2005; Davidson, 2007; Zharkova, Hewlett &Hardcastle, 2009). It provides a direct representation of tongue movements in speech, and allows for viewing most of the tongue contours during dynamic speech production. Electropalatography (EPG) is also considered as one of the main articulatory techniques that has been used for decades in research and treatment (Gibbon & Lee, 2011), which records the location and size of tongue-palate contact but not the tongue shape. Ultrasound image gives information on tongue contour relatively easily compared to other imaging techniques. Several recent research publications have reported on visual feedback therapy using ultrasound (Bernhardt, Gick, Bacsfalvi, & Ashdown, 2003; Bernhardt, Gick, Bacsfalvi & Bock, 2005; Bacsfalvi, Bernhardt & Gick, 2007) and of qualitative ultrasound analysis of communication disordered population (Bressmann, Radovanovic, Kulkarni, Klaiman & Fisher, 2011).

Ultrasound studies have been conducted in English and in Indian languages like Tamil, Telugu, Kannada and Hindi. Švarný and Zvelebil (1955) studied Telugu and Urdu, where speakers showed a lesser degree of retroflexion for Telugu. Ramasubramanian and Thosar (1971), Balasubramanian (1972, 1982) and Thananjayarajasingham (1976) studied retroflex in Tamil by using complemented palatograms with linguograms and X-ray tracing; their results showed 'more retroflexing'. Kochetov, Sreedevi, Manjula and Kasim (2012) studied Kannada retroflex, dental and velar sounds using ultrasound. As expected, the results showed distinct tongue shapes for retroflex, dentals, and velars. They also reported that retroflex consonants were predominantly sub-apical but the tongue body retraction is not an obligatory property of retroflexion. Further, overall displacement was greater for the vertical (raising) rather than horizontal (backing or fronting)

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movement of the tongue, during the opening rather than closing movement. Bernhardt, Gick, Bacsfalvi and Bock (2005) studied adolescents and adults where they used ultrasound as a feedback method for producing the correct sound. Results showed more of sub-apical appearance of tongue during the production of a retroflex. Song, Demuth, Hufnagel, and Ménard (2013) used ultrasound to study coarticulation during cluster production. Their study revealed that overall, children showed adult-like patterns in tongue curvature but with changes in tongue height. Zharkova (2013) considered two quantitative measures including dorsum excursion index and tongue constraint position index to quantify the ultrasound image of tongue dorsum in cleft palate articulations before and after intervention, to assess the reduction in tongue shape variability after speech therapy. Scobbie, Punnoos and Khattab (inpress) compared five liquids in Malayalam based on ultrasound images. They discussed the nature of the distinction between the tap and trill and between the alveolar and retroflex lateral and a fifth consonant /z/ which is a voiced sublamino palatal approximant. They opined that ultrasound is better than any other articulatory techniques and that ultrasound images revealed that rhotic/r, ɾ/ and laterals /l, ɭ/had relatively simple dynamic movement and liquid /z/, more complex blade motion.

The present study aimed to investigate the dynamic aspects of the tongue during the production of retroflex, dental and velar stop contrasts in Kannada. Investigative studies are very few across different places of articulation in Indian languages and are mostly limited to selected contrasts produced by single speakers of languages such as Hindi, Tamil, Telugu and Malayalam. Though Kochetov et al (2012) compared tongue shapes of retroflex with dental and velar sounds; they considered only adults as subjects. In this perspective, the present study aimed at comparing the dynamic features of the tongue for dental, retroflex and velar stop contrasts across children and adults in Kannada using ultrasound imaging technique.

Method

Participants: A total number of 20 subjects with equal number of children and adults participated in the study. All the participants were native speakers of Kannada and were not known to have any diseases or disorders. Children were in the age band of 9-10 years and adults, between 23- 25 years of age, with equal number of males and females. Participants were included for the study after oral mechanism examination.

Material : The test material consisted of three meaningful words including stops in three different places of articulation including dental /t/, retroflex/ T / and velar /k/. The words were /atta/, /aTTa/ and /akka/; the consonants occurred as geminates and were preceded and followed by vowel /a/. The low vowel /a/ context was chosen as it is considered to have the least possible coarticulatory effect on the consonant. Geminates were used to ensure that the ultrasound system could produce several frames of the consonant constriction duration. Geminate consonants in Kannada are described as twice as long as singletons, at least when occurring after short vowels (Schiffman, 1983).

Instrumentation: Mindray ultrasound 6600 connected with PC and installed with the software Articulate Assistant Advanced (AAA) ultrasound module Version 2.14 was used for the analysis with 60 frames per second. It is synchronized to the audio input with a sample rate of 22050 Hz. Hardware pulse generates a tone frequency of 1000 Hz with beep length of 50 millisecond to accurate the synchronization. The transducer is a long-handled micro convex probe operating at 6.5 mHz placed beneath the chin of the participant. The sound wave travels upward through the tongue body until it reaches and reflects back downward from the upper tongue surface. The upper tongue surface interface is typically with the palate bone and airway, both of which have very different densities from the tongue and cause a strong echo. For analysis, the software AAA uses the technique 'fan spline' which has 42 axes or points. Splines are curves defined by a mathematical function that are constrained to pass through specified points.

Data collection: Participants were made to sit comfortably and the test procedure was described to them. They were asked to sip water before the recording to moisturize the oral cavity facilitating better ultrasound images. The transducer probe placed beneath the chin was smeared with ultrasound transmission gel (*Aquasonic 100*) for better tongue imaging. The probe was fastened by stabilization headset (*Articulate Assistant Advanced*) to reduce the artifacts because of head movement. For recording the speech sample, a headphone (*iballi 333)* was used. Previously prepared stimulus list was presented visually on the computer screen to the participant and three repetitions of each prompt were considered for further analysis. Thus, nine utterances were recorded from each participant including three repetitions of three target samples. A total of 90 utterances were collected from both groups including males and females and a total of 180 utterances were recorded for the study ((5+5= 10*9= 90*2= 180) including both children and adults. Figure 1 is an ultrasound image of a child's tongue contour. The lower edge of the bright white curve is the surface of the tongue. The tongue tip is on the left and the black area below is caused by the bone of the chin.

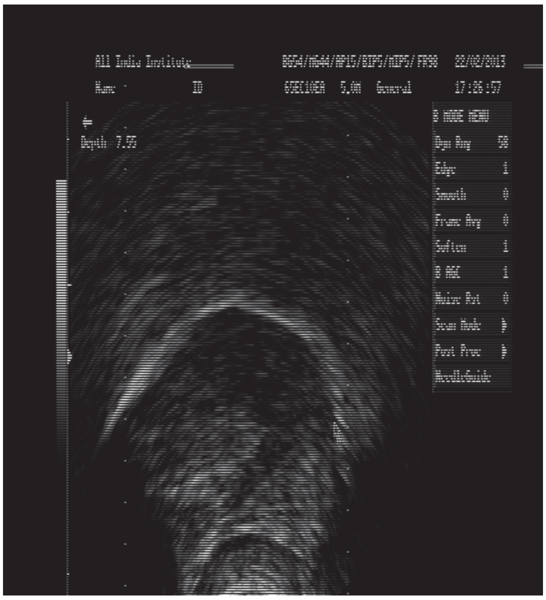

Figure 1: Ultrasound image at the consonant dental /t/ from the word /atta/ produced by a child speaker. Left side of the figure indicates the front of the oral cavity and right side shows back of the oral cavity.

Analysis : Fan spline setups were decided for each group and places of articulation, and used respectively since children's tongue contour requires narrow fan setup and for adult's it is wider. For dental and retroflex sounds, the fan was more towards the anterior region, and for velars, more towards the posterior region. Semiautomatic contour plotting was used in this study. The three frame images of each utterance were averaged in workspace to minimize the variation. 42 coordinal values of each contour were exported to text document to analyze the difference between two consecutive samples using Smooth Spline Analysis of Variance (SS-ANOVA). SS- ANOVA, a statistical method was used to compare two datasets to determine whether they are significantly different from each other. To describe the tongue contours, the tongue was divided in to three regions- the posterior tongue body, anterior tongue body and the tongue front, if it is visible (Davidson, 2006).

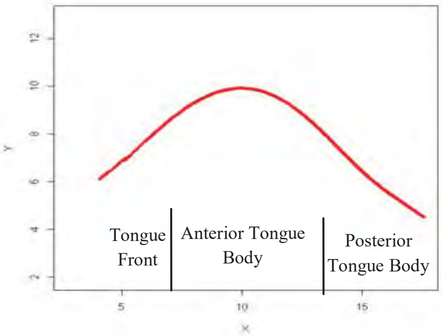

Figure 2: Schematic representation of divisions of tongue contour into three regions- the posterior tongue body, anterior tongue body and the tongue front. The vertical (Y) and horizontal (X) scale is in mm.

The analysis was performed using *assist package* (Version 3.1.2) of R programming language (Version R 2.15.2; www.r-project.org). Overall, three SS-ANOVAs were run for comparing places of articulation across children and adults.

Results

On examination of the ultrasound images of adults and children based on SS-ANOVA, the tongue contour, as expected was different for all the three places of articulation, /k/, /T/ and /t/. Tongue contour in children showed more variations compared to adults. Figure 3 shows tongue contours for velar place of articulation for children and adults separately in the word /akka/. In both groups, contours are of similar pattern but the overall height of the adult's tongue contour is more compared to children, especially for the anterior tongue body. Tongue front shows much proximity between children and adult tongue contours and posterior tongue body is more towards back for adults compared to children. In addition, a broad tongue contour was present in adults where as children showed narrower appearance.

Figure 4 shows the comparison between children and adults tongue contour for the production of retroflex in the word /aTTa/. The pattern of tongue shape is similar for both groups but for the height of the tongue, which is more in adults. Tongue front is comparatively high in children, anterior and posterior body of tongue lowered compared to adult's pattern. As seen in velar production, the broadness of tongue contour was more in adults than children. Tongue curling for retroflex sounds indicated as angle of retroflection was not very evident in both children and adults.

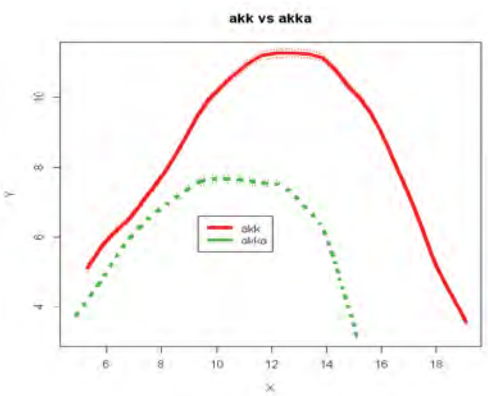

Figure 3: Comparison of tongue contour between children and adults for the production of /akka/ (Dotted and solid lines indicate tongue contours of children and adults respectively).

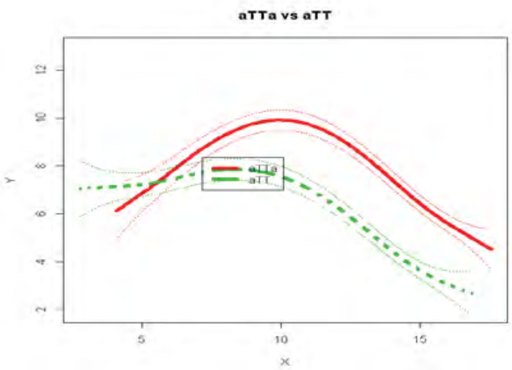

Figure 4: Comparison of tongue contour between children and adults for the production of /aTTa/ (Dotted and solid lines indicate tongue contours of children and adults respectively).

On similar lines, Figure 5 shows the comparison of tongue contours between children and adults for the production of dental plosive in the word /atta/. For /t/ also, the height of the tongue contour of adults is more than children but the pattern of tongue contour was similar for both groups. The broadness of tongue contour shows more over similar appearance.

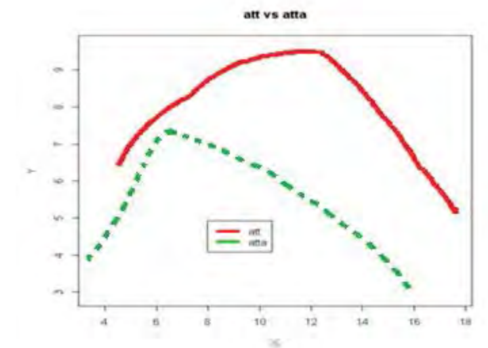

Figure 5: Comparison of tongue contour between children and adults for the production of /atta/ (Dotted and solid lines indicate tongue contours of children and adults respectively).

Discussion

Present study aimed at comparing the dynamic features of the tongue for different places of articulation such as dental, retroflex and velar stop contrasts in native Kannada speaking children and adults using ultrasound tongue imaging technique. The results showed different tongue contours for each place of articulation, which is in agreement with the findings of Kochetov et al (2012) who studied Kannada with the same test sample. This implied distinct place features of each sound.

As per the present study, children showed more variations in tongue contours compared to adults, which is in agreement with Zharkova (2013), who studied children with cleft palate. In the present study, the tongue height was more for adults than children which indicates larger size of the oral cavity and tongue in adults. The overall pattern similarity between children and adults across places of articulation indicates motor maturation of active articulators in children. These findings are in agreement with the study of Song et al (2013) who studied adolescent and adults coarticulation. However the present findings need to be confirmed with larger population of children in different languages.

The angle of retroflection was not prominent in the present study and is similar to the reports of Kochetov et al, 2012 in Kannada. Švarný and Zvelebil (1955) also reported that Telugu showed comparatively less retroflection than Urdu. For Tamil, however, the findings were more of sub-apical palatal constriction for retroflex sounds (Ramasubramanian & Thosar, 1971; Balasubramanian, 1972, 1982; Thananjayarajasingham, 1976). Some of the studies (Bernhardt et al, 2005; Lawson et al, 2011) in English reported sub-apical retroflection of the tongue. This indicates that the angle of retroflex varies across languages and that retroflection is apical often rather than sub-apical which may depend on the language spoken.

Conclusions

The current study aimed to compare the dynamic features of the tongue for dental, retroflex and velar stop contrasts in native Kannada speaking children and adults using ultrasound imaging technique. The results showed similar patterns of tongue contours for both groups with the overall height of the adult's tongue contour being more compared to children, especially for the anterior tongue body region. The angle of retroflection was not prominent in both groups and indicated that retroflex sound production is not always sub-apical as it is presumed to be. This study augments our understanding about the tongue dynamics, which in due course can be related to the communication disordered population.

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