Percent of tongue anteriority during protrusion in speech: the “th” sound

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INTRODUCTION AND GOAL

Our goal is to look specifically at how the “th” sound is created in humans. Is it made with primarily protrusion of the tongue tip? Contrary to its simplicity and visibility, its not found in many languages. Thus, the “th” sound will be explored to see if movements other than primary protrusion are contributing to the formation of the “th” sound making it a more complex movement.

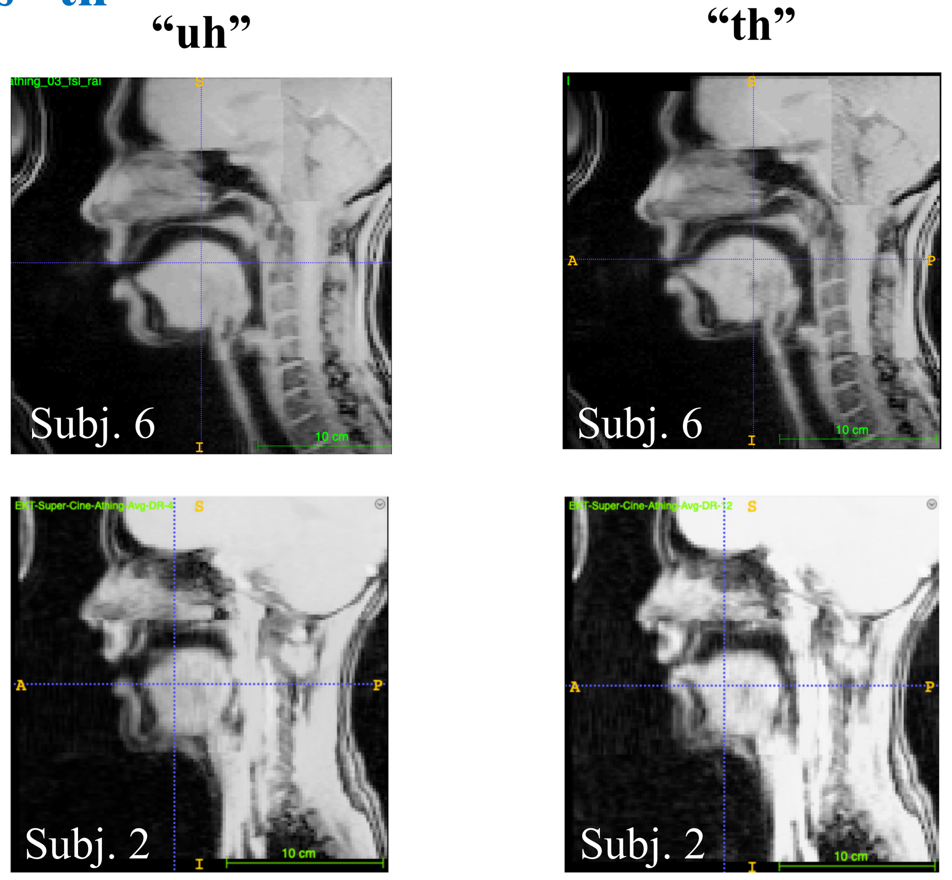
To test this, the word “a thing” will be used. “uh” places the vocal tract in a neutral shape. This position allows for a comparable starting point across subjects. When “th” in “thing” is uttered the vocal tract and tongue will change to a deformed state to create protrusion.

A newborn baby at week 36 of pregnancy has fully developed a sucking reflex. When the roof of the baby’s mouth is touched this signals to the hypoglossal nucleus to begin sucking or in other terms to begin a primitive form of protruding and retruding of the tongue. Further development allows for differentiation, such as co-contraction of muscles or swallowing motions due to activation of muscles in a more complicated way. Although all tongue development starts with protrusion, it is strange that “th” sound, is not more universal across languages.

SUBJECTS:

- 10 Healthy native English speakers ages 23-40

Fig. 1. MRI Image of subject 2 & 6 at “uh” vs “th”



Using cine MRI, a sagittal slice can be created to view the tongues deformation, location, and position relative to other structures in the mouth. While uttering “uh” the tongue and vocal tract are in the first position. Creating the ”th” sound (right picture) the subject must protrude his tongue against the lingual side of their teeth.

MATERIALS AND METHODOLOGIES

MRI DATA:

- High-resolution anatomical MRI data were collected in 3 orthogonal directions (sag, axial, coronal) in order to extract tooth roots:
  - In-plane resolution: 0.97 mm/pixel (voxel = 1 x 1 x 3 mm)
  - Slice thickness: 3mm
  - Field of view: 24cm
- Lower resolution Cine MRI data were also collected in three planes to extract tongue volume
  - In-plane resolution: 1.87 mm/pixel (voxel = 2 x 2 x 6 mm)
  - Slice thickness: 6mm
  - Field of view: 24cm
- A Supervolume creates an isovoxel by interpolating intervening slices from the 3mm (6mm) slice resulting in a 1 x 1 x 1 mm voxel (2 x 2 x2 mm voxel)

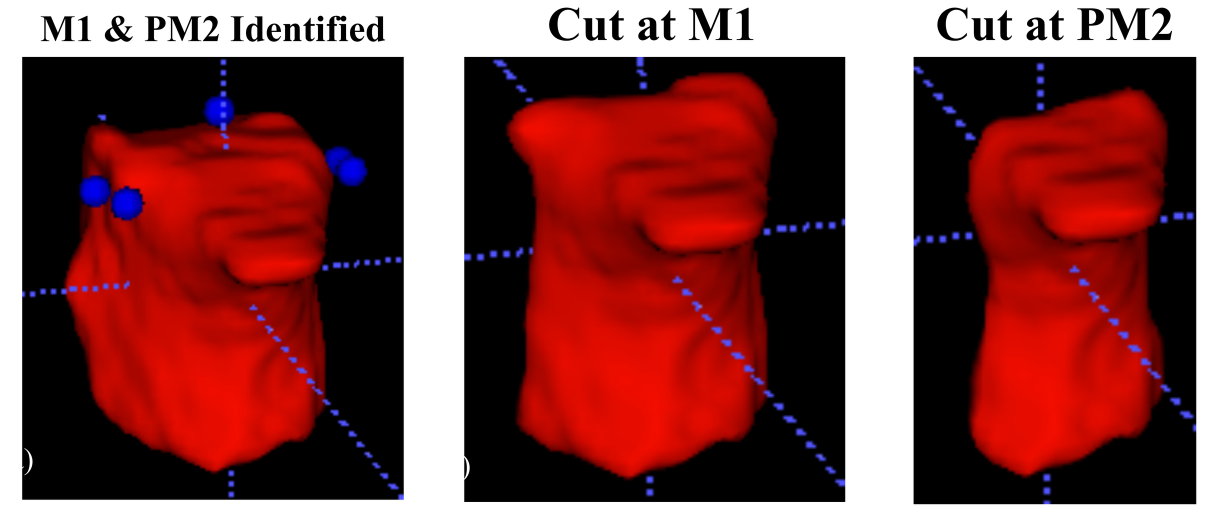
ANTERIORITY CALCULATION:

- From the supervolumes, the entire volume of the tongue was segmented, its location within the mouth was noted, the 1st molar (M1) , 2nd premolar (PM2) were identified, as well as the palate surface perpendicular to the bisection of the M1. This was done at two-time frames: ”uh” and “th”
- In ITK Snap[1] a 3D constructed model was used, to position a plane through the palate point and M1. The plane was then translated anteriorly to PM2 and another plane was placed in the 3D model. These planes were used to cut the volume and used to measure the anterior tongue volume. (see Figure 2)

$$\text{\% difference of anteriority from “uh” to “th at M1} = \left(\frac{vol_{ant.to\ M1\ at\ “th”}}{vol_{whole\ tongue}}\right) - \left(\frac{vol_{ant.to\ M1\ at\ “uh”}}{vol_{whole\ tongue}}\right)$$

$$\text{\% difference of anteriority from “uh” to “th at PM2} = \left(\frac{vol_{ant.to\ PM2\ at\ “th”}}{vol_{whole\ tongue}}\right) - \left(\frac{vol_{ant.to\ PM2\ at\ “uh”}}{vol_{whole\ tongue}}\right)$$

Fig. 2. Segmented tongue volumes in subjects



3D constructed model of subject 2 using ITK Snap. (a) The whole tongue with teeth M1, PM2, and palate points identified. (b) Tongue volume anterior to M1. (c) Tongue volume anterior to PM2.

RESULTS

Fig. 3. Primary moving portion of tongue

Controls	1	2	3	4	5	6	7	8	9	10
Primary moving portion of tongue	Body	Tip	Body	Body	Body	Body	Body	Body	Body	Body

Fig. 4. Hold-one-out graphs

- Box and whisker plots were calculated 10 times, each one holding out one subject to detail each subject’s protrusion behavior
- In the left column, the graphs display a small amount of movement from “uh” to “th” at M1 and PM2, except for subject 2
  - Subject two has more motion at PM2 than M1
- The right column of graphs have a large amount of motion at M1 and PM2 except subject 6
  - Subject 6 has very little motion in PM2

DISCUSSION

- Subject 2 (highlighted in blue) was the sole primary tip mover. There is much larger percent change in anteriority at PM2 in comparison to M1. This shows that the tip of there tongue is primarily responsible for the protrusion movement in “th”.
- In fact the entire right column shows a lot of movement in the M1 and less at PM2 suggesting that the protrusion is not accomplished by squeezing and lengthening the tip but pulling the whole tongue forward.
- The left column had subjects who moved the tongue very little. Suggesting they are not protruding or pulling the tongue forward very much. Perhaps it’s the jaw assisting tongue, or their tongue is anterior to begin with.
- In both columns a greater percentage of tip anteriority than body anteriority is not seen except in subject two.

Limitations:

In order to conduct the MRI, all subjects were lying supine. Due to gravity’s affect, the tongue will sit more posterior in the oral cavity. The “uh” sound should create a uniform space within the vocal tract. However, in fig. 2, subject 2’s vocal tract narrows as you move superiorly due to the affect of laying supine while in the MRI. This distorts the neutral starting position, possibly altering later comparisons.

CONCLUSIONS

- Even though this is a small study 9 out of 10 subjects did not use a protrusive motion similar to the simple protrusions found in suckling or animals who catch flies.
- Despite all subjects being healthy controls a marked variability was observed. Subjects exhibit diverse tongue deformations in order to utter “a thing.”
- When comparing subjects to patients in future studies, there should be special attention to the variability in ways “a thing” can be produced. What is considered within normal limits should be expanded in order to accommodate this newfound adaptability.

REFERENCE

1. Paul A. Yushkevich, Joseph Piven, Heather Cody Hazlett, Rachel Gimpel Smith, Sean Ho, James C. Gee, and Guido Gerig. User-guided 3D active contour segmentation of anatomical structures: Significantly improved efficiency and reliability. Neuroimage 2006 Jul 1;31(3):1116-28.

ACKNOWLEDGMENTS

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