

# Exploring Human Tongue Mobility Without Surrounding Bone Structure

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## Background

- The human tongue is classified as a **muscular hydrostat (MH)**, as it uses hydrostatic pressure as mechanical support instead of a bony skeleton (e.g., Kier & Smith, 1985)
- Prior studies suggest some **tongue** functions are **dependent** on interaction with **surrounding** skeletal structures (Hiemae & Palmer, 2003)

## Hypothesis

- **Bone structure** surrounding the tongue is **important** for the **production** of **speech-like** tongue shapes

## Prediction

- We predict that the **presence** of **bone** should correspond to a **lower range** of tongue movement but allow for **more complex** tongue shapes

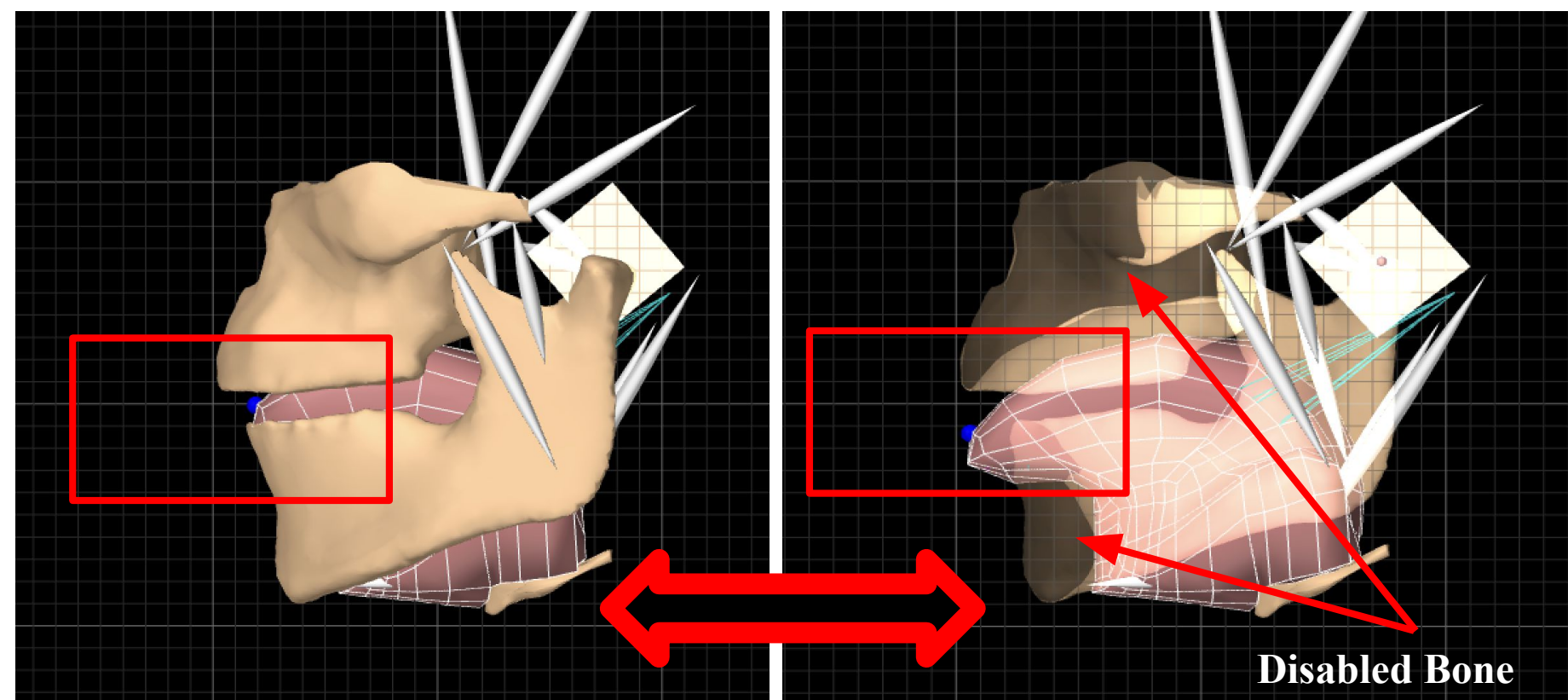
## Methods

- **Artisynth**: 3D Interactive biomechanical simulation platform (Lloyd, J. et al., 2012)
  - Java-based API for model creation
- Jaw-Hyoid-Tongue complex model to run simulation

## Methods cont.

### Experimental Variables:

- **Input**: varying degrees of **excitation** of muscles + presence of **bone** (hard palate, mandible, and maxilla)
  - 10 muscles with two possible states of excitation: 0% and 25%
    - ( $2^{10}$  combinations) + bone (on/off) = **2048** different trials
- **Output**: coordinates (x, y, z) of points on tongue

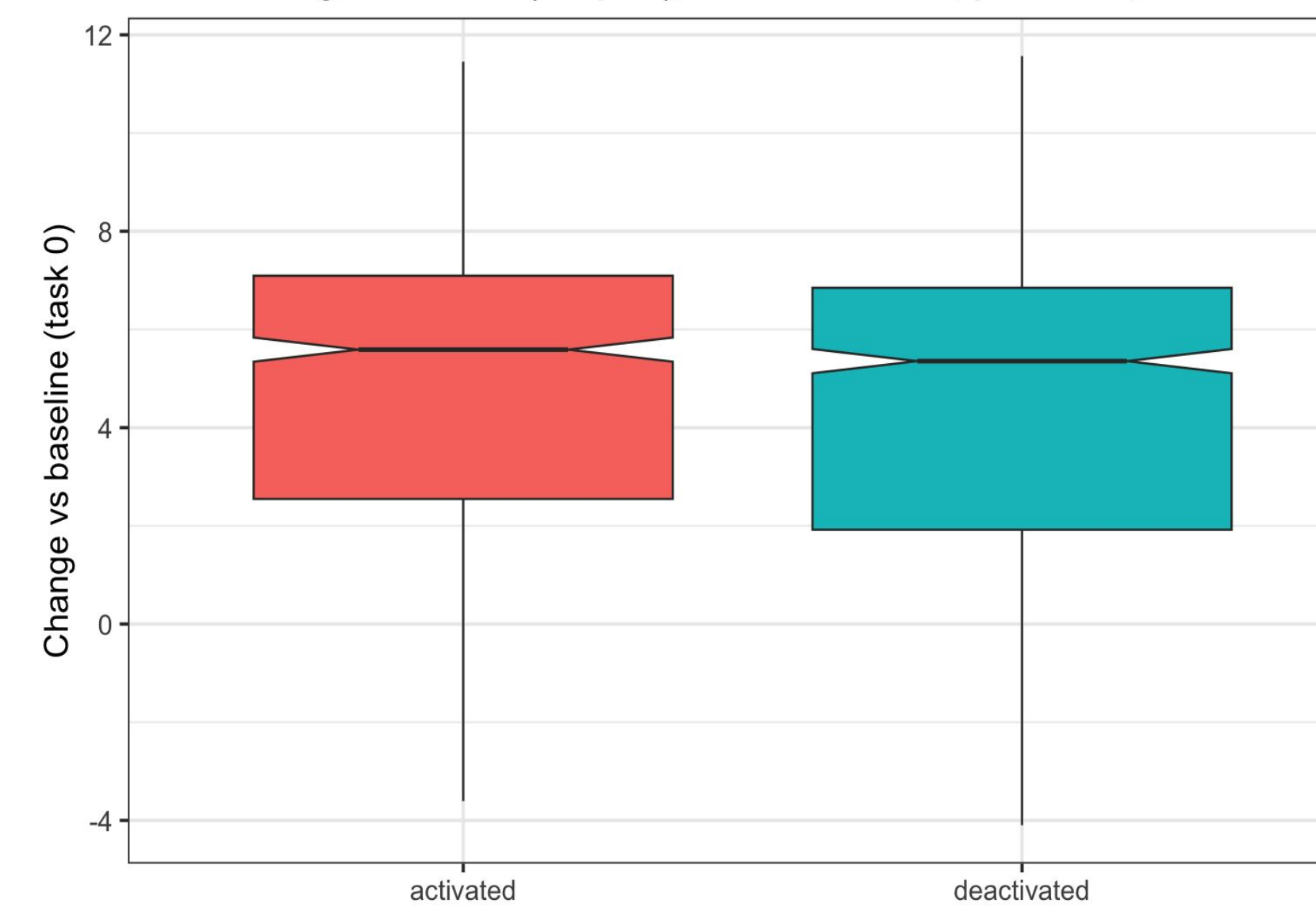


### Metrics

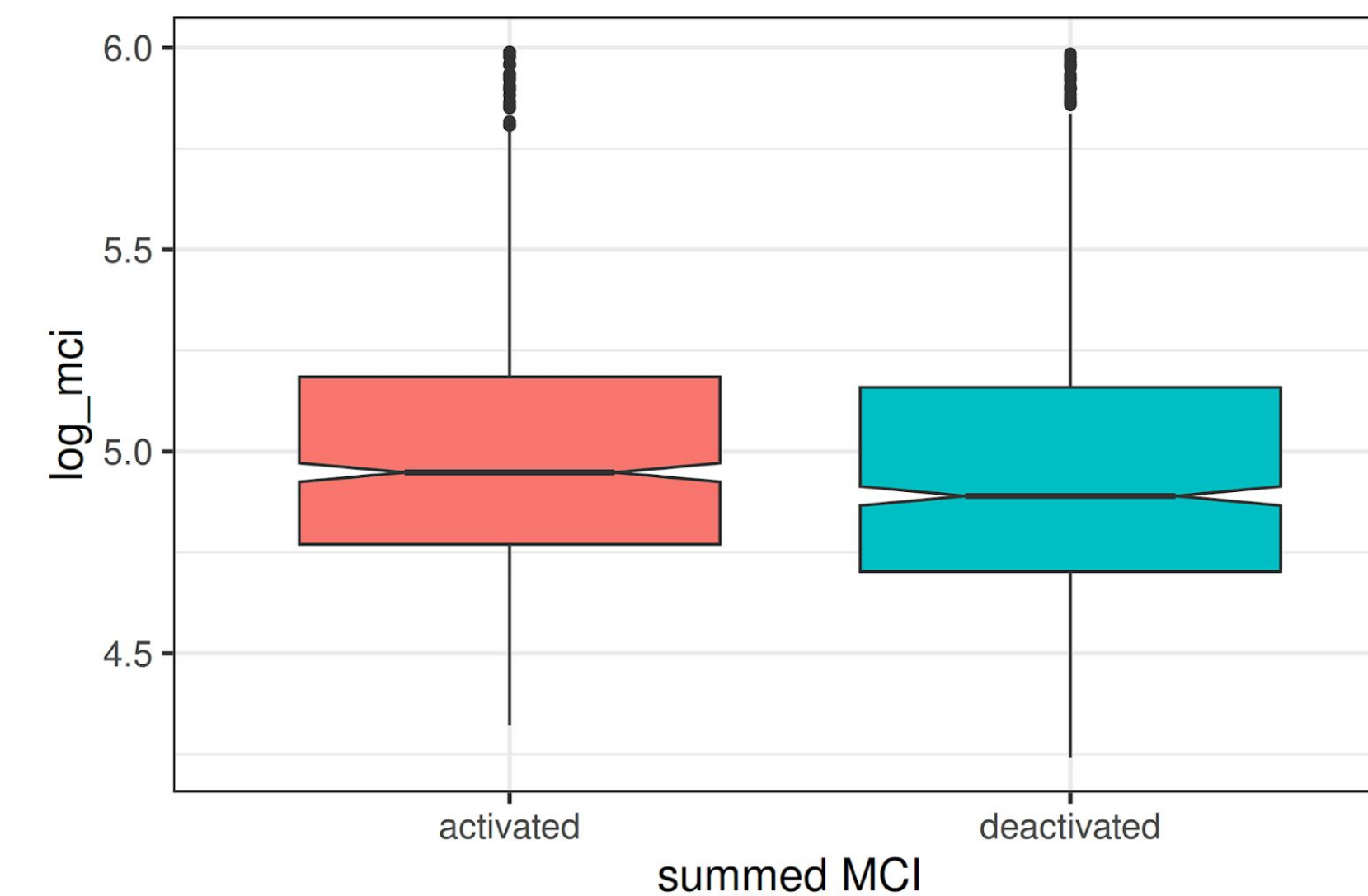
- **Tongue Stretch**
  - **Forward Stretch**:  $\Delta$  distance along the sagittal axis
  - **Lateral Stretch**:  $\Delta$  distance along the coronal axis
- **Tongue Shape Complexity**: Modified Curvature Index (MCI) (Dawson et al., 2016)
  - 2D measure of tongue curvature
  - Summed MCI for each row & column of tongue grid for 3D complexity

## Results

- Conducted **Welch's two-sample t-test**
  - **Forward Stretch** = tends **higher without** bone ( $p = .057$ )
  - **Lateral Stretch** = **higher with** bone ( $p < .001$ )



- **Shape Complexity** = **higher with** bone ( $p = .016$ )



## Discussion

- Support hypothesis: surrounding **hard structures** **constrain** tongue movement but also **allow** for more **complex** tongue **shapes**.
  - **Palatal structures** may be important for achieving **lateral tongue stretch**
- Clear similarities with other MHs but the tongue's reliance on and interaction with **hard structure** may be a **crucial point of difference**
- Understanding this interaction is **essential** for characterizing **human tongue function**
  - Clinical practice + function & evolution of hydrostatic muscular systems in general

## Next Steps

- Test more extreme excitations (50%) + more metrics of tongue mobility
- Analyze qualitatively about what kind of shapes get produced by different trials

## References

- (1) Hiemae K.M. & Palmer J.B. (2003). Tongue Movements in Feeding and Speech. *Critical Reviews in Oral Biology & Medicine*, 14(6):413-429. doi:10.1177/154411130301400604
- (2) Kier, W. M., & Smith, K. K. (1985). Tongues, Tentacles and Trunks: The Biomechanics of Movement in Muscular-Hydrostats. *Zoological Journal of the Linnean Society*, 83(4), 307-324. <http://dx.doi.org/10.1111/j.1096-3642.1985.tb01178.x>
- (3) Lloyd, J. E., Stavness, I., & Fels, S. (2012). ArtiSynth: A fast interactive biomechanical modeling toolkit combining Multibody and finite element simulation. *Studies in Mechanobiology, Tissue Engineering and Biomaterials*, 355-394. [https://doi.org/10.1007/8415\\_2012\\_126](https://doi.org/10.1007/8415_2012_126)
- (4) Roewer-Despres, F. (2018, June 29). The Batch Simulation Framework. (3).pdf
- (5) Dawson, K. M., Tiede, M. K., & Whalen, D. H. (2016). Methods for quantifying tongue shape and complexity using ultrasound imaging. *Clinical linguistics & phonetics*, 30(3-5), 328-344. <https://doi.org/10.3109/02699206.2015.1099164>

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