Biomechanical Simulation of Lip Compression and Spreading

Connor Mayer[1], Chenhao Chiu[2], Bryan Gick[3,4]

[1] University of California, Irvine
[2] National Taiwan University
[3] University of British Columbia
[4] Haskins Laboratories

Quantal effects in speech

Speech exploits ***quantal*** properties of the vocal tract

Acoustics

Large Δ in articulator position

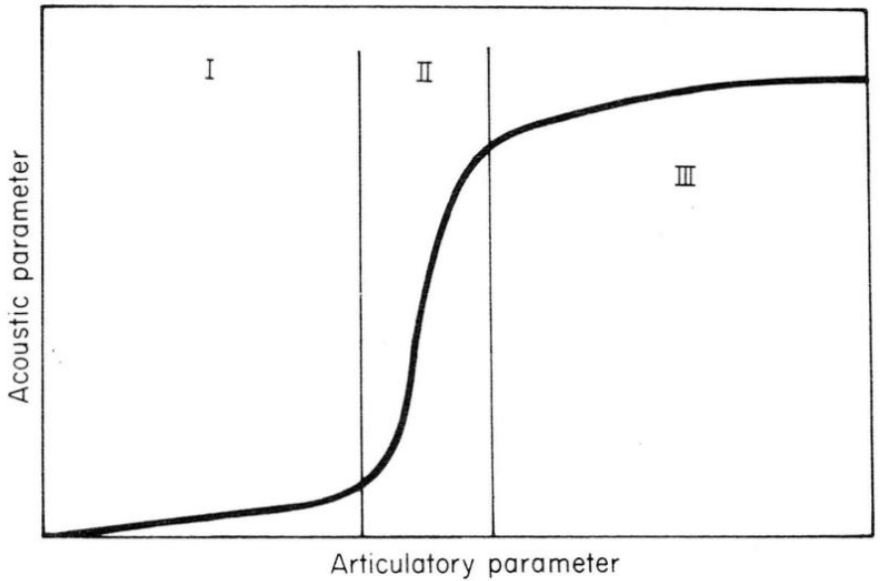
→ minimal Δ in acoustics (Stevens 1989)

Biomechanics

Large Δ in muscle activation

→ small Δ in articulator position

Predicted to exist for the lips (Fujimura 1989)



The lips in speech

Biomechanical simulation has found quantal effects for various labial movements used in speech (Nazari et al. 2011, Stavness et al. 2013, Gick et al. 2011, 2020)

Rounding

Closure

Labiodental

Lip spreading and closure

Two prevalent labial postures have not been studied from this perspective

Spreading

Corners of lips drawn back

E.g., English /i/

Compression

Lip aperture narrowed without much accompanying protrusion

E.g., Mandarin /y/; Japanese /ɯ/, /ɸ/

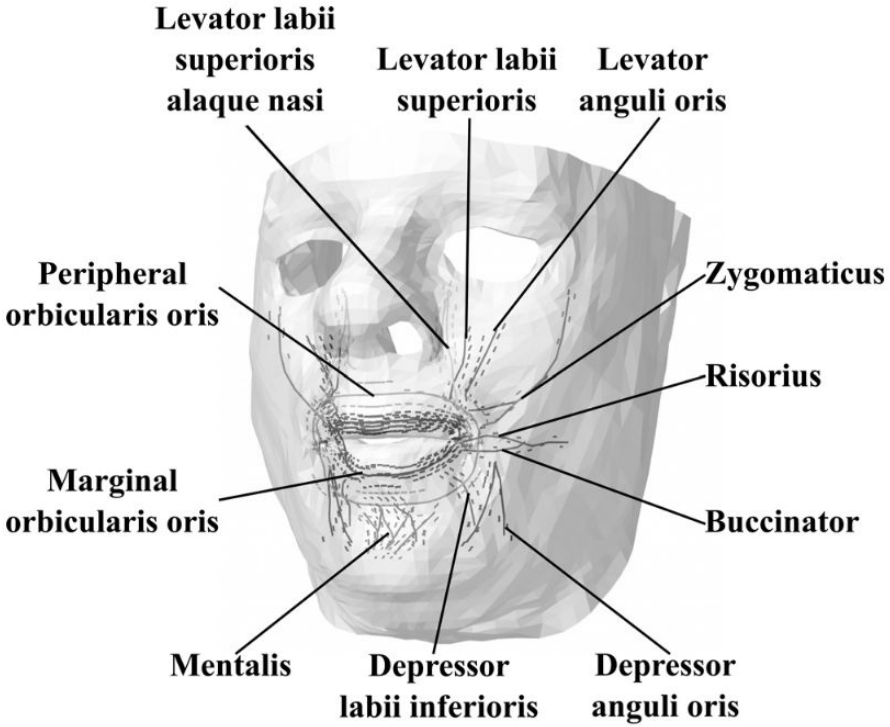
Goals of this study

1. What are muscle groupings that drive lip spreading and compression?

2. Do these groupings display quantal properties?

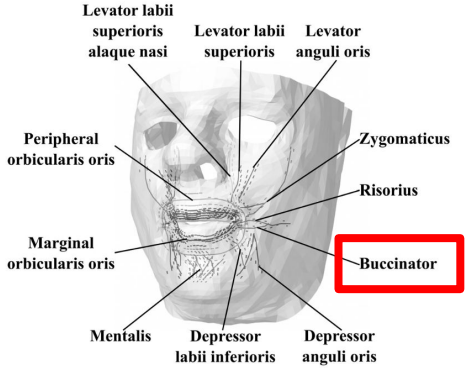
Simulation Methods

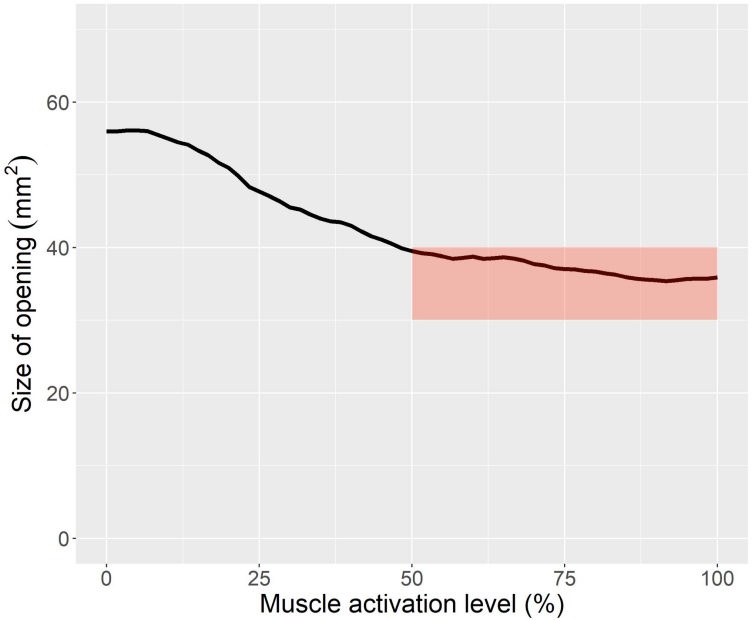
- Badin FEM face model in Artisynth (artisynth.org)
- Identify muscle groupings and relative maximum activation levels that produce appropriate postures
- Activate from 0-100% of maximum activation and measure lip opening



Simulation 1 Results: Spreading

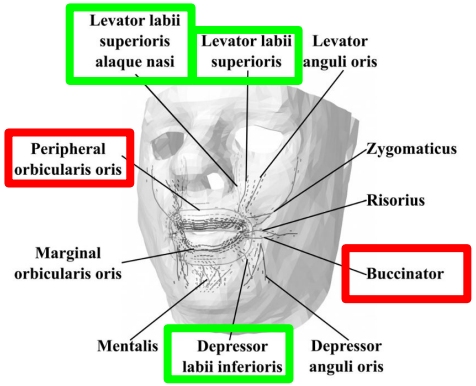
BUC 50 kPa

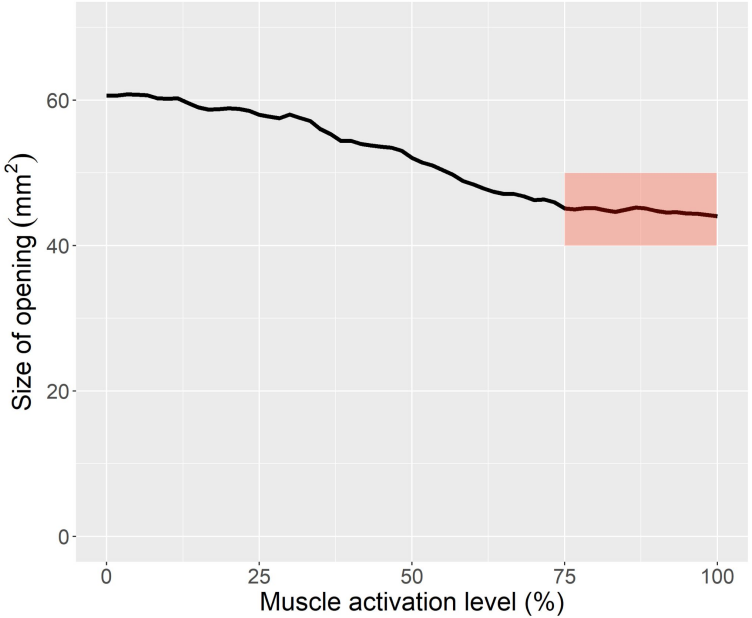


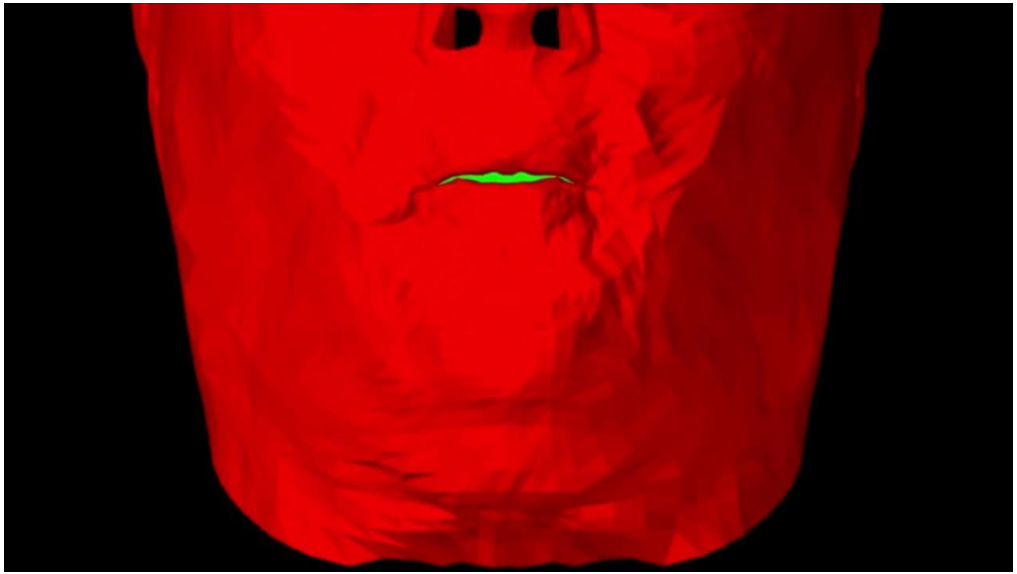


Simulation 2 Results: Compression

OOP	70 kPa	LLS	30 kPa
BUC	30 kPa	LLSAN	20 kPa
		DLI	45 kPa







Discussion

1. What are muscle groupings that drive lip spreading and compression?
    - Spreading relies primarily on BUC
    - Compression involves interaction between muscles that close the lips and muscles that open them
    - Broadly consistent with experimental literature (e.g., Ohman et al. 1965, Hadding et al. 1976)

2. Do these groupings display quantal properties?
    - Yes!
    - Supports claim that speech movements exploit regions of biomechanical stability

Acknowledgements and references

This work was supported by NIH grant DC-002717 to Haskins Laboratories.

Fujimura, O. (1989). Comments on ‘On the Quantal Nature of Speech’ by K.N. Stevens. *J. Phon, 17*: 87-90.

Gick, B., Stavness, I., Chiu, C., and Fels, S. (2011). Categorical variation in lip posture is determined by quantal biomechanical-articulatory relations. *Canadian Acoustics, 39*(3): 178-179.

Gick, B., Mayer, C., Chiu, C., Widing, E., Rower-Despres, F., Fels, S., and Stavness, I. (2020). Quantal biomechanical effects in speech postures of the lips. *J. Neurophysiol., 124*(3): 833-843.

Hadding, K., Hirose, H., and Harris, K.S. (1976). Facial muscle activity in the production of Swedish vowels: An electromyographic study. *J. Phon., 4*(3): 233-245.

Nazari, M.A., Perrier, P., Chabanas, M., and Payan, Y. (2011). Shaping by stiffening: a modeling study for lips. *Mot. Contr., 15*: 141-168.

Ohman, S., Leanderson, R., and Persson, A. (1965). Electromyographic studies of facial muscles during speech. *Speech Trans Lab, Status Report, 3*: 1-11.

Stavness, I., Nazari, M.A., Perrier, P., Demolin, D., and Payan, Y. (2013). A biomechanical modeling study of the effects of the orbicularis oris muscle and jaw posture on lip shape. *J. Speech Lang. Hear. Res., 56*: 878-890.

Stevens, K.N. (1989). On the quantal nature of speech. *J. Phon., 17*: 3-45.