CROSS-LINGUISTIC BRACING: A LINGUAL ULTRASOUND STUDY OF SIX LANGUAGES

Lauretta Cheng[1*], Murray Schellenberg[1†] and Bryan Gick[‡1, 2]
[1]University of British Columbia, Vancouver, British Columbia, Canada
[2]Haskins Laboratories, New Haven, Connecticut, USA

1 Introduction

Lateral bracing refers to persistent and active contact of the sides of the tongue along the upper molars or palate. Evidence from articulatory analysis of native English speakers as well as from 3D biomechanical simulations suggests that bracing of this kind provides mechanical support consistently throughout speech (Gick et al. 2017, Stone 1990). Release of lateral bracing occurs only during some instances of low vowels and lateral consonants. The current study tests for the presence of active lateral bracing in single-speaker case studies of six languages: Cantonese, Korean, Mandarin, Portuguese, Spanish, and Turkish. Based on the point of view that tongue bracing is a fundamental aspect of human speech production, we hypothesize that tongue bracing should exist in speech regardless of language.

2 Method

Six speakers of different native languages (Cantonese, Korean, Mandarin, Portuguese, Spanish, Turkish) were asked to read translated passages of the North Wind and the Sun (International Phonetic Association, 1999) in a fluent reading manner, three times each in both English and in their native language while a coronal ultrasound video (Aloka PROSound SSD-5000) of their tongue was recorded in B/M-mode with a six-second sweep speed and with vertical intersect lines placed at three points along the tongue: tongue midline (M), left (L) edge and right (R) edge (see Figure 1). The probe was positioned to capture the video at a coronal cross-section intersecting the tongue roughly as far back as the upper molars. The accompanying audio was also recorded.

The movement of the tongue at the three positions was traced and measurements of the vertical motion were taken from still frames of the M-mode ultrasound videos (each frame displays six seconds of movement trajectory). Active lateral bracing is implicated if the left and right edges of the tongue are (i) less variable in vertical motion than midline and (ii) positioned at a stable baseline height for a larger percentage of time than they are lowered. Two measures are used to assess these criteria: (i) within-speaker comparisons of the amount of variability in vertical movement between central (midline) vs. lateral (left and right edge) positions, and (ii) proportion of time during which one or both sides of the tongue move below a fixed point on the ultrasound. For the variability measure, vertical movement distances were extracted at every pixel along the traced line for each position. For the pervasiveness measure, a baseline height was determined from the line tracings of each speaker and the duration of tongue height below baseline ("releases") is measured. The bottom half of Figure 1 shows vertical displacement trajectories (in yellow) as the tongue moves through the three intersect lines. Percentage of speech that is laterally braced is compared across speakers.

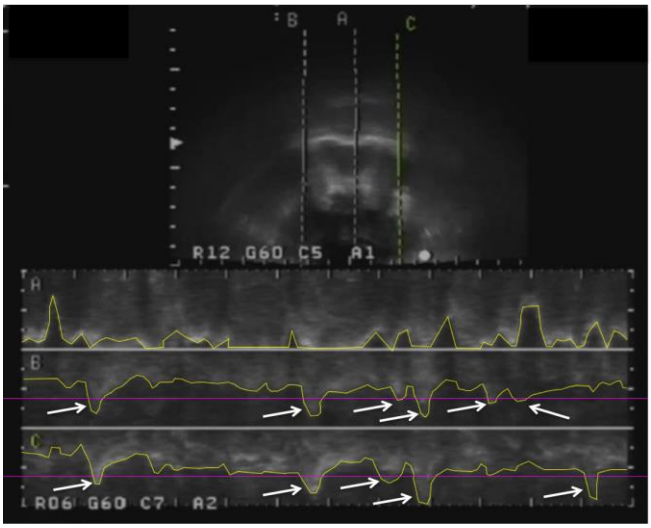

Figure 1: Ultrasound image in M-mode for mid (A), left (B), and right (C) positions on tongue. The horizontal lines represent the baseline cut-off and the arrows mark the events identified as discrete instances of lateral release.

3 Results

Figure 2 shows the mean vertical displacement of the tongue through the three intersect lines, by speaker. This figure indicates how much the tongue moves vertically along each of the 3 lines (Left, Middle and Right); higher values here indicate greater movement. The graphs indicate greater movement of the tongue midline than of either edge, suggesting more stable placement of the lateral edges of the tongue than the midline throughout speech. It is also interesting to note that all of the speakers seem to move the left side of the tongue more than the right side.

* lauretta.cheng@alumni.ubc.ca
† mhschellenberg@gmail.com
‡ gick@mail.ubc.ca

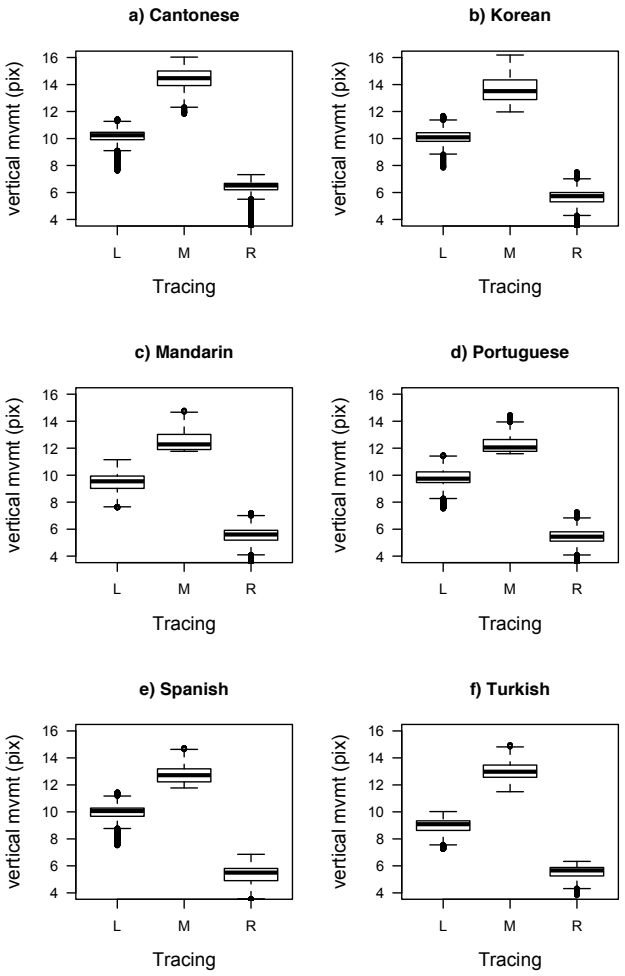

Figure 2: Box and whisker plots of vertical movement for each tongue position. Higher values indicate greater movement.

A series of ANOVAS with post hoc Tukey tests was run with vertical movement as the dependent variable and tracing as the independent variable for each language. For all languages both left and right side movement of the tongue was significantly different from movement of the centre ($p<0.001$ in all cases).

For each side of the tongue, the maximum and mode of vertical movement y-values of each tracing were taken. We assume the mode is not laterally released so that anything between the mode and the maximum is natural variation. We assume the same amount of variation below the mode as well. We subtracted the difference (vertical distance) between the maximum and mode y-values from the mode y-value, resulting in separate baseline y-values for left and right sides. The more conservative value was then used as the final baseline y-value for both sides of the tongue for each individual. This can be seen in Figure 1 where the horizontal lines superimposed on the M-mode tracing for B and C represents the baseline. The events marked with the arrows are treated as occasions of lateral release.

Table 1 shows the proportion of the total time of the recorded speech that either one or both sides of the tongue moved below the baseline position. While the amount of time with lateral release varied between speakers, all speakers kept both sides of their tongue raised between 78.02% (Mandarin) and 96.77% (Cantonese) of the time.

Table 1: Proportion of speech time with lateral release expressed as a percentage of total time.

LANGUAGE	PROPORTION RELEASE
Cantonese	3.23%
Korean	8.82%
Mandarin	21.98%
Portuguese	14.43%
Spanish	13.58%
Turkish	18.78%

4 Discussion and conclusions

All six speakers showed significantly more movement of the middle of the tongue than of the sides of the tongue (Figure 2), and all six speakers spent the majority of their speaking time with the sides of their tongues held in a raised position (Table 1). The speaker who held the sides of the tongue lowered for the longest proportion of time (the Mandarin speaker) still maintained a raised tongue position almost 80% of the time. The range of time varies considerably but it must be noted that although all speakers read a version of The North Wind and the Sun, these passages are not balanced for phoneme frequency so the number of phonemes which require loss of lateral bracing differs considerably from one translation to the next.

These results support our hypothesis that lateral tongue bracing is maintained throughout running speech not only in English but in a variety of languages.

Acknowledgments

The authors wish to thank the six speakers for participating in this study and special thanks to Colin Jones, Victoria Choi and Kate Curtis for their help with analysis.

References

[1] Gick, B., Allen, B., Roewer-Després, F., & Stavness, I. (2017). Speaking tongues are actively braced. *Journal of Speech, Language, and Hearing Research*, 60(3), 494-506.

[2] International Phonetic Association. (1999). *Handbook of the International Phonetic Association: A guide to the use of the International Phonetic Alphabet*. Cambridge University Press.

[3] Stone, M. (1990). A three-dimensional model of tongue movement based on ultrasound and x-ray microbeam data. *The Journal of the Acoustical Society of America*, *87*(5), 2207-2217.