INITIATION AND MAINTENANCE OF LINGUAL BRACING POSTURE

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1 Introduction

Lateral bracing, in which the sides of the tongue are held in contact with the palate and upper molars [1], has been found to be maintained throughout running speech, across all languages observed to date [2]. This braced posture is released only for select sounds, including laterals (such as [l] in English) and low vowels (such as [ɔ]) [3], and is even maintained through non-lingual and lingually neutral sounds such as labial and glottal consonants which require no lingual movement, and schwa [3], which has a neutral tongue position [4].

The present study aims to examine these non-lingual and neutral contexts to determine whether lateral tongue bracing is a transient activation or a tonic activation that spreads onto unspecified, neutral sounds. We hypothesize that the raised (braced) and lowered (unbraced) tongue postures function as distinct postural settings that are maintained through sequences of lingually neutral sounds, suggesting that such postures may be initiated by a preceding postural "trigger."

2 Methods

2.1 Participants

Twenty-two participants took part in this study and were recruited through the SONA linguistics portal at the University of British Columbia (UBC) or by word of mouth. 5 participants were excluded from analysis because they were not native speakers of North American English (NAE) according to a language background questionnaire; participants were considered to be native speakers if they acquired English before eight years of age and continued to use it as a primary language at work, school, or home. The data from another 9 participants were excluded due to poor ultrasound image quality. The remaining 8 participants were native speakers of NAE and were students at UBC between the ages of 18 and 22. In order to adhere to COVID-19 safety protocols, masks were worn by the participants throughout the experiment.

2.2 Experiment

Participants were seated in an experiment chair with a headrest stabilization mechanism. An ultrasound probe was positioned to view a coronal image of the posterior portion of the participant's tongue. The recording of audio and ultrasound video was then started.

Participants were presented with a series of stimuli consisting of four blocks of sentences, each of which consisted of seven sentences. The target word present in each sentence was "hubba-bubba" [həbəbəbə] (HB), which was selected because it contains a sequence of four syllables made up entirely of non-lingual and lingually neutral sounds. Flanking this target sequence were words containing either lingual consonants, sounds that require tongue bracing (e.g., chews, wants, has, eats, chewing gum) or /l/, a sound known to interfere with tongue bracing (e.g., love, lump, plum, lots). The blocks were randomized so that participants read one of twenty-four possible block orders in their stimuli. Participants were asked to read the entire set of stimuli three times, the first acting as a practice round.

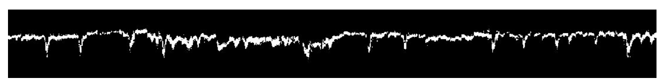

Figure 1: Thresholded VKG of data from the left side of the tongue for one participant. Tracing of the tongue surface is shown in white pixels.

2.3 Analysis

Analysis A: The spreading of lingual bracing (ultrasound): The timestamps of HB within the second and third stimuli reading in each video file were extracted from manual TextGrid annotations using Praat [5]. All frames of the ultrasound imaging video were extracted, and only the frames within each utterance of the manually labeled target word were selected for further analysis. ImageJ software [6] was used to open each set of image sequences, adjust their brightness and contrast in order to more clearly see the tongue's surface and then threshold the images to black and white. Finally, the image sequences were converted into videokymographs (VKG) in ImageJ, creating an image of the tongue's tracing over time (shown in white pixels) for each utterance of HB. Separate VKGs were produced for the left and right sides of the tongue.

The side of the tongue with the clearest and most consistent imaging was selected for further analysis. From the chosen VKGs, the tongue position at the beginning of each HB sequence was examined. We then normalized the original tongue position in pixel values for comparison across participants with z-scores. The normalized initial tongue positions of HB produced in different conditions (braced vs unbraced) were fitted into a linear mixed effect (LME) model with preceding condition as a fixed effect and speaker as a random effect with both random slope and intercept. In order to determine whether the preceding target could

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cause a triggering effect of bracing, the LME model was compared to a null model without a preceding condition as a fixed effect using a likelihood ratio test.

Analysis B: Acoustics of the spreading of lingual bracing: An acoustic analysis was conducted on participants' production of each of the two central [bə] syllables in the HB sequence (i.e., [həbəbəbə]). We chose the central [bəbə] syllables in order to minimize possible effects of local coarticulation with the preceding and following segments. The first two vowel formants (F1 and F2) were extracted at the midpoint of each [bə] syllable and the average of F1 and F2 across the two syllables was calculated. In order to determine the effect of preceding condition on the vowel formants of schwa in HB, we fitted mean F1 and F2 values of the central [bəbə] syllables in a similar LME model as in Analysis A and compared the model with a null model using a likelihood ratio test.

3 Results

3.1 Lorem ipsum dolor sit amet

Analysis A: The spreading of lingual bracing (ultrasound): After comparing the tongue height of 56 HB productions from 8 participants, results (see figure 2) show that the sides of the tongue remain in a significantly higher position when preceded by a braced target compared (mean height in z-score 0.43) to an unbraced target (mean height in z-score -0.45) ($p<0.001$).

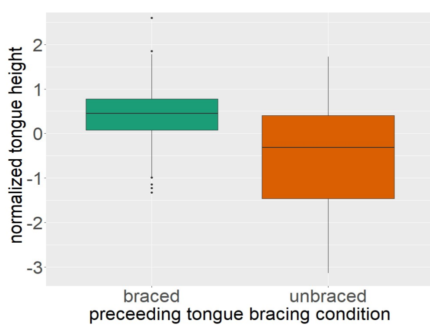

Figure 2: Boxplot depicting the normalized mean tongue height during the production of HB for the 8 speakers analyzed in braced vs. unbraced preceding conditions.

Analysis B: Acoustics of the spreading of lingual bracing: Mean F1 and F2 values of the central [bəbə] syllables of HB are shown in Figure 3. Neither F1, F2 values were significantly different between the preceding target conditions.

4 Discussion

Our results suggest that the maintenance and suppression of the lateral tongue bracing posture spreads to the following non-lingual productions. Given that the preceding context appears to act as a trigger for the following segments, this may indicate that the tongue toggles or switches between these two postures, braced and unbraced.

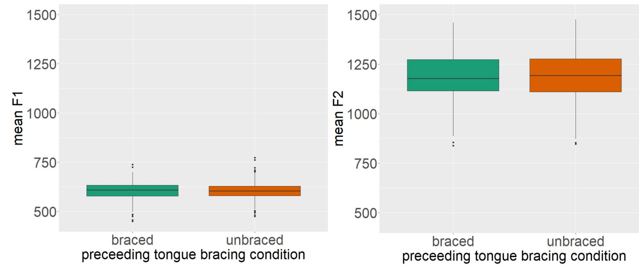

Figure 3: Boxplot depicting normalized mean F1 and F2 during the production of the two central ([bəbə]) syllables of HB for the 8 speakers analyzed in braced vs. unbraced preceding conditions.

As no significant effects of braced or unbraced condition were found on F1 and F2 values, this suggests that not all changes in tongue behaviour/position lead to significant changes in acoustic output.

Some notable limitations to our study which future research should attempt to overcome include the limited sample size and the fact that using ultrasound only shows tongue height and cannot definitely show tongue-palate contact. Also, since tongue contour was not always visible in the regions of interest, some position data was lost throughout collection with the ultrasound [2]. Future work will involve running the present experiment with a larger sample size and investigating the carryover and anticipatory influence of lateral tongue bracing posture.

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