TONGUE BRACING ROBUSTNESS UNDER PERTURBATION: THE MODERATING EFFECT OF LANGUAGE EXPERIENCE

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1 Introduction

Lateral tongue bracing ('LTB'), where the sides of the tongue brace against the hard palate and upper teeth, has been established by previous literature as an active posture [1] that is maintained throughout speech across multiple languages [2]. LTB persists throughout most sounds, except for some lateral consonants and low vowels [1]. In line with non-speech postures, LTB is demonstrated to persist in perturbed conditions [3]. Compared with speech in one's more experienced language ('EL'), Bengtson et al. [4] find significantly less LTB in participants' speech in their less-experienced language ('LL'), suggesting it is less robust under perturbation. Such an explanation is in line with the relationship between experience and the robustness of non-speech posture under perturbation established by previous literature [5].

However, Bengtson et al. [4] do not include a baseline condition comparing unperturbed EL and LL speech, leading to two possibilities to explain the observed results. It could be that (1) amount of LTB decreases in LL speech with the presence of perturbation or (2) there is generally less LTB in LL speech and the presence of perturbation does not make a difference. Existing evidence suggests that language proficiency could impact unperturbed pre-speech posture [6]. Only the former scenario is consistent with the experience–robustness interaction hypothesis [4]. The current study seeks to fill in the gap through a comparison between with- vs. without-bite-block conditions and EL vs. LL conditions. We hypothesize that the amount of language experience will impact the robustness of the LTB posture under perturbation. We predict that compared to a baseline of EL speech, in LL speech the amount of LTB during speech will decrease more significantly from without–bite-block ('nBB') to with–bite-block ('wBB') conditions.

2 Method

The present study looks at the amount of LTB using coronal ultrasound imaging (adapted from [2]).

2.1 Participants

Twenty-one participants were recruited through the SONA Linguistics system at the University of British Columbia, with 12 discarded due to poor imaging or video quality. Nine speakers were analysed, with 4 EL-LL combinations : English-French, English-Spanish, Mandarin-English, and Japanese-English. Participants self-reported EL and LL.

2.2 Procedure

Participants sat in a chair with an adjustable headrest to stabilize their heads. An ultrasound transducer was held below the chin of the participants through a stable chair arm, positioned to show coronal imaging. There were in total 4 reading tasks in the experiment, namely EL nBB, EL wBB, LL nBB, and LL wBB. Passages were made without labial consonants and minimal rounded vowels since lip closure would move the bite-blocks. Participants finished the two nBB reading tasks consecutively and the two wBB reading tasks consecutively. Within the bite-block conditions, participants read both passages twice. Before data collection, participants read and familiarized themselves with both passages. During the two wBB reading tasks, participants read the passages with two 10mm bite-blocks held by the top and bottom molars on each side of the mouth as the external perturbation to the tongue.

2.3 Analysis

To trace vertical movement of the lateral tongue, ultrasound video was first converted into image sequences using videokymography (henceforth VKG – example in figure 1).

FIGURE 1 – An example of a thresholded VKG showing the vertical tongue movement (represented by the white line). Dips in the graph represent reduced (or entirely released) lateral bracing.

Frames with missing values were interpolated based on neighbouring pixels. The amount of LTB of each individual speaker under each condition was calculated by the variance of lateral tongue height (determined by the y-value of the bottom-most white pixel for each frame of the VKG) during speech. Greater variance is thought to predict less LTB overall (i.e., more releasing during speech). Within each speaker, data from the same side of the tongue was used for all conditions, and mean values of variance across two repetitions were taken for those whose both repetitions were applicable.

3 Results

3.1 Paired-sample t-test

Figure 2 shows that tongue height had the greatest degree of variance during wBB LL speech, and the least during nBB EL speech.

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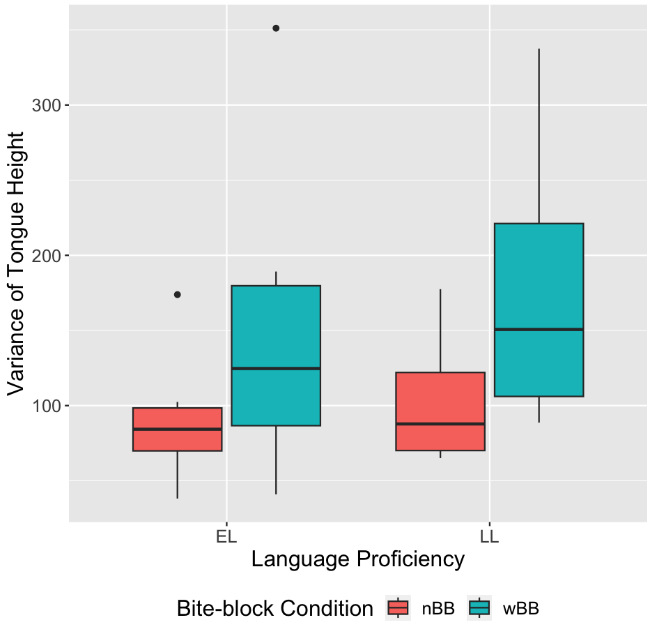

FIGURE 2 – Box-plot comparing the variance of tongue height for one side of the tongue between nBB (red) and wBB (blue) conditions, spoken in participants' EL (left) and LL (right) languages.

Two paired-sample t-tests, one each for nBB and wBB, were conducted to determine the effect of language experience on tongue height variance. The results indicated that the variance of lateral tongue height significantly increased from EL to LL in the wBB condition ($t(8)$ = -2.961, p = 0.02) but not in the nBB condition ($t(8)$ = -1.441, $p > 0.1$).

3.2 Linear mixed-effects model

To further investigate the interaction between perturbation and language experience, a linear mixed-effects model was fit using the *lmerTest* R package [7] run with the variance of lateral tongue height as the dependent variable. Fixed effects were included for bite-block conditions (nBB ; wBB), language experience (EL ; LL), and their interaction, and random intercepts were included for participants. Results from the linear mixed-effects model are displayed in Table 1. With nBB and EL as the baseline, results of the linear mixed-effects models revealed a significant effect of wBB on tongue height variance ($t(27) = 2.245$, $p = 0.033$) at a significance value of $p < 0.05$. For the LL condition ($t(27) = 0.499$, $p = 0.622$) and interaction between wBB and LL ($t(27) = 0.471$, $p = 0.642$), there was no significant effect.

TABLE 1 – Table of linear mixed-effects model results with fixed conditions of bite-block condition (wBB vs. nBB), language experience (EL vs. LL), and bite-block condition & language experience condition interactions.

Fixed Effect	**Est.**	***SE***	***t***	***p***
(Intercept)	87.36	21.38	4.086	< 0.01
wBB	59.21	26.38	2.245	0.033
LL	13.15	26.38	0.499	0.622
wBB :LL	17.56	37.30	0.471	0.642

4 Discussion

The present study investigated how much language experience affects the robustness of lateral tongue bracing under perturbation. A lower variance of side tongue height denotes greater stability and less releasing.

The paired t-test results suggest that the insertion of bite-blocks causes significantly more lateral releasing in LL compared to EL speech. This supports our hypothesis and could potentially be explained by a cumulative effect of the difficulty induced by internal inexperience (i.e., less-familiar speech posture inventory) and external perturbation (c.f. motor-cognitive load [8]).However, the linear mixed-effects model showed that bite block insertion significantly increased variance in tongue height, but neither language experience nor their interaction had significant effects. A notable limitation is the small number of participants and language pairs due to difficulty in capturing usable ultrasound data, which may possibly explain the null results in the linear mixed-effects model.

To further investigate the effect of language experience on the robustness of LTB, future work can be done by increasing the sample size, e.g., by bootstrapping or collecting more participants.

Acknowledgments

This study was conducted under ethics code H19-01359 Embodying Speech and supported by an NSERC Discovery grant to the last author. We thank Yadong Liu and Jahurul Islam for methodological advice, Abiodun Samuel Ibikunle for data collection and analyses, and Brian Diep for acting as a pilot participant.

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