LINGUAL CONFIGURATION OF AUSTRALIAN ENGLISH /l/

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ABSTRACT

English /l/ is a multi-gestural segment produced with dorsal retraction and lowering and a central alveolar closure. The coordination of antagonistic coronal and dorsal gestures prototypically results in lingual elongation. Although intergestural coordination in laterals has been widely studied, less is known about articulatory configuration in Australian English /l/ —a dialect characterised by coda /l/-lenition [1, 2]. We explored tongue elongation as a potential metric of /l/-lenition. The timecourse of lingual elongation was examined in laterals produced by two Australian English speakers using electromagnetic articulography. Tongue elongation was greater in onsets and codas containing laterals compared to onsets and codas containing /d/. Coda laterals showed less elongation than onset laterals. Quantifying lingual elongation can potentially differentiate onset /l/ from lenited or vocalised /l/ across a variety of vocalic and consonantal contexts by capturing a key characteristic of /l/ in environments where coronal and dorsal gestures are often unmeasurable.

Keywords: laterals, goals of /l/ articulation, /l/-vocalisation, Australian English

1. INTRODUCTION

The English lateral approximant and its allophonic variation between clear, dark, and vocalised /l/ has been studied widely both because of its social salience and implications for syllable structure [1, 3, 4, 5, 6, 8, 9, 10, 15, 16, 18]. /l/-vocalisation —the realisation of /l/ with no alveolar closure —has been studied with articulatory [7, 12, 13, 17] and acoustic impressionistic [1, 8, 9, 10] methods, showing that the likelihood of /l/-vocalisation depends on the place of articulation of adjacent segments.

However, /l/-articulation is hard to measure, as articulatory analysis requires contrasting /l/ gestures with the gestures of surrounding segments. As the coronal gesture of /l/ does not contrast with following homorganic alveolar consonants, some studies avoided a following alveolar [e.g., 16, 21] or used it as a baseline to elicit unvocalised /l/ [13, 14]. As the tongue dorsum gesture is similar to that of back vowels [5], some studies have focused on lateral production only in front vowel contexts [e.g., 16, 18, 22]. /l/-vocalisation is characterised by lenition of tongue tip contact; therefore, it is difficult to capture before a coronal consonant because a tongue tip gesture can be attributed both to the alveolar consonant and to /l/. Auditory impressionistic classification can distinguish vocalised and non-vocalised /l/ [e.g., 1]; however, that is an indirect measurement.

We aimed to develop a technique that has the potential to quantify and characterise /l/ lenition and vocalisation by tracking change in tongue elongation during /l/ production. Tongue elongation results from /l/ having complex articulation: /l/ involves the simultaneous raising and/or fronting of the tongue apex and retraction of the tongue dorsum [6, 11, 18], resulting in lingual elongation along the midline of the vocal tract [11, 15]. In contrast, coronal stops and non-front vowels would not be expected to show tongue elongation as coronal stops do not require tongue retraction and non-front vowels do not require tongue tip fronting. Vocalised /l/ may be expected to show reduced tongue elongation, as it is articulated without a tongue tip contact with the alveolar ridge [6, 7]. This suggests that tongue elongation might be a metric that can distinguish non-vocalised /l/ from vocalised /l/. To capture tongue elongation, we computed the distance between the tongue tip and the tongue dorsum during /l/ production in front, back, and low vowel contexts. We also compared tongue tip and tongue dorsum trajectories of /l/ to /d/ to determine how they contribute to tongue elongation. We hypothesised that (1) in accordance with previous research, the tongue would be more elongated in /l/ than in /d/ in all vowel contexts; and (2) onset /l/ might be more elongated than coda /l/, due to potential lenition or vocalisation of coda /l/.

2. METHODS

2.1. Participants

Two female native speakers of AusE participated in the study. Participants were students of linguistics, naive to the purpose of the experiment, who did not report any hearing, speaking, or reading difficulties. Participants received $80 for their time.

2.2. Material

Twenty-four unique monosyllabic words containing /iː, ɪ, ɐː, ɐ, oː, ɔ/ were selected from an experimental corpus (Table 1). Target words combined real words of varying frequency and non-words. Although /l/-vocalisation is sensitive to lexical frequency [13], we did not find a difference in tongue tip position and elongation between real words and nonwords in a pilot with one participant. Target words were elicited in a carrier phrase with antagonistic vowel contexts: "*far; __ HARP*" and "*fee; __ HEAP*" for front and non-front vowels respectively. Non-target consonants were /p/, /f/, or /h/ to minimise lingual coarticulation. A semicolon was introduced after the first word to minimise resyallbification between target and carrier phrase. The last word was set in capitals to maintain consistent prosody across trials.

Table 1: Target words without carrier phrase.

Vowel Context		/d/		/l/	
		Onset	Coda	Onset	Coda
Front	/iː/	*deep*	*peed*	*leap*	*peel*
	/ɪ/	*dip*	*pid*	*lip*	*pill*
Back	/oː/	*dorp*	*poured*	*lorp*	*Paul*
	/ɔ/	*dop*	*pod*	*lop*	*pol*
Low	/ɐː/	*darp*	*pard*	*larp*	*parl*
	/ɐ/	*dup*	*pud*	*lup*	*puhl*

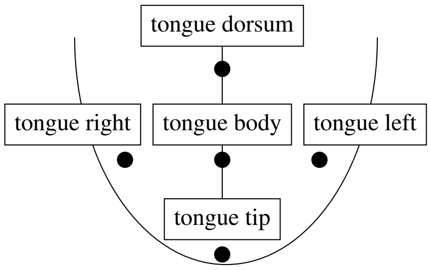
2.3. Procedure

Participants were seated approximately 50 cm from a computer screen and were introduced to the task and the experimental materials with a short practice block. Participants read the phrases aloud. Each trial began with a blank screen for 500 ms, followed by the stimulus for 2000 ms. After 2000 ms, the experiment automatically moved on to the next trial. Items were presented once per block in a random order. The block was repeated 8 times, providing 192 target words per participant.

2.4. Data acquisition

Articulatory data were acquired using an NDI Wave system sampling each sensor at a rate of 100 Hz. Eleven sensors were attached to the participant. Five sensors were attached to the tongue to track lingual articulation: three midsagittal (tongue tip (TT), tongue body, tongue dorsum (TD)) and two parasagittal sensors (right and left) (Fig. 1). One

Figure 1: Tongue sensor placements viewed from top.

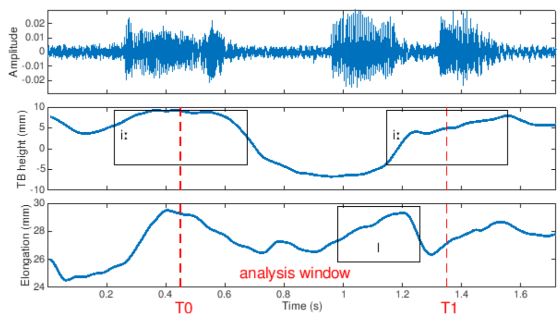


sensor was attached to the lower and one to the upper lip to track lip aperture and rounding. A sensor was attached to the lower gumline to track jaw movement. Three reference sensors (nasion, left and right mastoid) were used to correct for head movement. The occlusal plane was located with a bite trial and the palate was traced with a palate probe.

2.5. Data analysis

24 (targets) × 8 (repetitions) × 2 (participants) = 384 tokens were recorded. 14 tokens (4 from W1, 10 from W2) were excluded from analysis due to being misread, leaving 370 tokens for analysis. A maximal analysis window was defined from the midpoint of the vowel gesture in the first word (T0) to the midpoint of the vowel gesture in the last word (T1) of the carrier phrase (Fig. 2). That is, for the phrase *fee; Paul HEAP*, the gestural midpoint of /iː/ in *fee* was selected as T0, and the gestural midpoint of /iː/ in *HEAP* was selected as T1 (Fig. 2). For each token, the gestures defining the analysis window were determined visually using MView [19]. From this window, unfiltered trajectories of TT and TD movement were extracted [20]. We calculated a tongue elongation trajectory (TE) as the Euclidean distance between the TT and TD sensors (horizontal and vertical positions) at each point in time.

Figure 2: Analysis window exemplified by *fee Paul HEAP*. Top panel: waveform. Middle panel: vertical location of tongue body. Bottom panel: tongue elongation. Boxes mark gestures. T0 marks the start of the analysis window at the gestural midpoint of the first vowel and T1 marks the end at the gestural midpoint of the last vowel.



We analysed tongue movement trajectories in the selected window using generalised additive modeling (GAM) [20]. GAM is a non-linear regression model which can be used to analyse change in articulatory trajectories over time by computing the best-fitting non-linear basis function for a trajectory [20].

TE, and horizontal and vertical TT and TD trajectories were time-normalised to account for differing length of the trajectories and modeled separately for both speakers and both positions; as a result 5 (trajectories) $\times$ 2 (participants) $\times$ 2 (onset and coda) = 16 models were built. We modeled TE, TT, TD trajectories as the function of consonant segment (/l/ compared to baseline /d/) and vowel context (front and back vowels compared to baseline low) using GAM with thin plate regression splines as basis functions. Random effects were not added as speakers were modelled separately.

3. RESULTS

3.1. Tongue elongation

Tongue elongation was greater in /l/ than in /d/ for W1 in both syllable onset ($\beta = 0.88, F(1,8714) = 7.48, p = 0.006$) and coda ($\beta = 0.74, F(1,9050) = 6.18, p = 0.01$). For W2, tongue was more elongated in /l/ than in /d/ in the onset ($\beta = 1.96, F(1,5492) = 11.85, p < 0.001$), but less elongated in the coda ($\beta = -0.47, F(1,5146) = 7.79, p = 0.005$) (Fig. 3). Tongue elongation occurs in the first half of the analysis window in onset /l/, and in 50%–80% of the analysis window in coda /l/ for W1 (Fig. 4). Greater tongue elongation in W2's coda /d/ might be an artifact of a too-large analysis window as the tongue seems to be more elongated in /l/ than in /d/ in 50%–75% of the analysis window, and less elongated elsewhere (Fig. 4). Tongue elongation in onset and coda /l/ was not compared in the same model; however, comparing estimates across models indicates greater tongue elongation in onset than in coda /l/.

3.2. TT and TD trajectories

Tongue tip and tongue dorsum were fronted during the production of /l/ compared to /d/ in onset and coda position for both speakers (Table 2, TTx and TDx trajectories). Tongue dorsum was lowered during the production of /l/ compared to /d/ in coda position for both speakers, and in W1's onset (Table 2, TDz trajectories). Tongue tip gesture of /l/ was only lowered compared to /d/ in W1's coda. TT fronting was always greater than TD fronting, except for W2's coda (Table 2, β). TT and TD trajectories are illustrated by W1's production, as W2 produced a similar pattern (Fig. 5).

Figure 3: Change in tongue elongation over normalised time (T0 to T1). Left: /l/ vs. /d/ in onset. Right: /l/ vs. /d/ in coda. Top: W1. Bottom: W2. Shaded bands show 95% confidence intervals. Red vertical bars mark greater tongue elongation associated with /l/ as in Fig. 4.

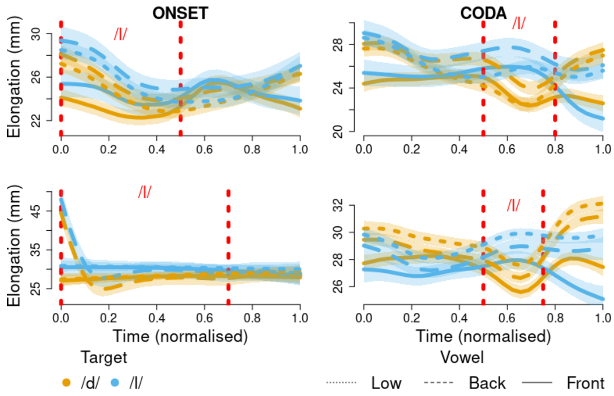
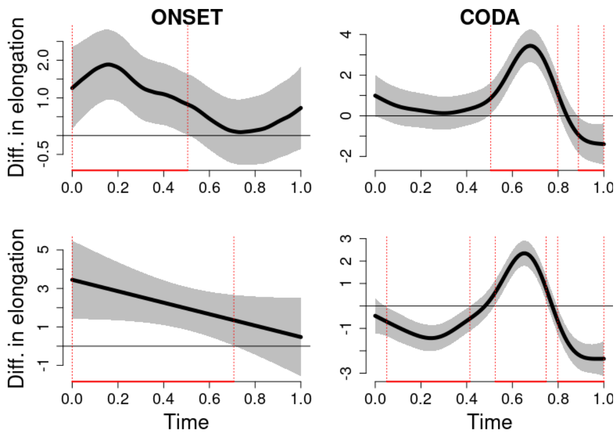


Figure 4: Difference in tongue elongation over normalised time (T0 to T1) comparing /l/ to /d/. Left: /l/ vs. /d/ in onset. Right: /l/ vs. /d/ in coda. Top: W1. Bottom: W2. Shaded bands show 95% confidence intervals. Red lines on the X-axis and red vertical bars indicate areas of significant difference.



4. DISCUSSION

The aim of this study was to develop a metric of tongue elongation that can potentially quantify /l/-vocalisation. In accordance with our first hypothesis and previous research [3, 11], the tongue was more elongated in /l/ than in /d/, except for W2's codas. Tongue elongation may distinguish /l/ from surrounding segments, whereas the tongue tip gesture of /l/ is similar to coronal stops and the tongue dorsum gesture is similar to non-front vowels. Thus, the tongue elongation metric could be used to automatically identify the point in time at which lingual elongation is maximised in different environments.

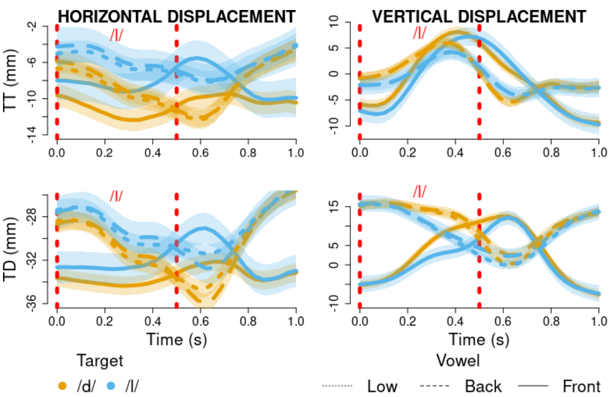
Tongue elongation may occur because of the fronting of the tongue tip and the lowering of the

Table 2: Effect of /l/ on TT and TD. TTx and TDx: horizontal movement. TTz and TDz: vertical movement.

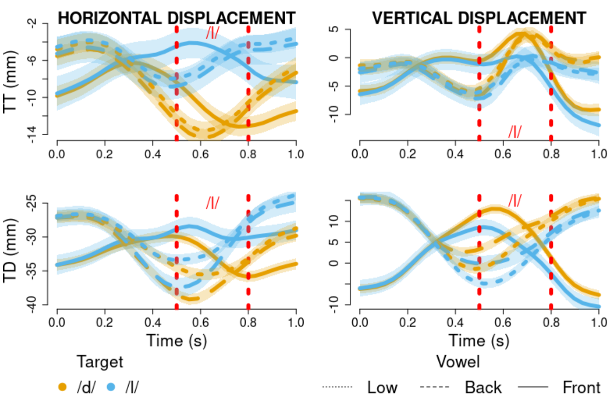
Position	Speaker	Trajectory	β	p
Onset	W1	TTx	2.49	< 0.001
		TDx	1.51	0.001
		TTz	-0.68	0.2
		TDz	-1.88	0.01
	W2	TTx	3.83	< 0.001
		TDx	2.35	< 0.001
		TTz	0.02	0.95
		TDz	0.47	0.63
Coda	W1	TTx	3.26	< 0.001
		TDx	2.25	< 0.001
		TTz	-1.40	0.002
		TDz	-2.43	< 0.001
	W2	TTx	0.98	< 0.001
		TDx	1.33	0.002
		TTz	0.56	0.11
		TDz	-3.17	0.001

Figure 5: Change in TT and TD movement over normalised time (T0 to T1) in W1's speech. Left: horizontal displacement. Right: veritcal displacement. Top row: TT. Bottom row: TD. Shaded bands indicate 95% confidence intervals. Red vertical bars mark greater tongue elongation associated with /l/ as in Fig. 4.

(a) Analysis window contains /d/ and /l/ in onset position.



(b) Analysis window contains /d/ and /l/ in coda position.



tongue dorsum gestures. Both tongue tip and dorsum are fronted in /l/ compared to /d/, but greater fronting in the tongue tip compared to the dorsum fronting leads to elongation. The more extensive tongue tip fronting may indicate that only the tongue tip gesture of /l/ has a fronted target, whereas tongue dorsum fronting might result from being coarticulated with the tongue tip.

In W1's speech, the magnitude of tongue elongation of /l/ compared to /d/ was greater in syllable onset than in coda, which is consistent with our second hypothesis, showing lenition in coda /l/. Although the tongue tip was more fronted in coda compared in onset position, it was also lowered, indicating lenition. This finding indicates that reduced tongue elongation may provide a consistent measurement of coda /l/ lenition in a variety of segmental contexts. In contrast with tongue elongation, tongue tip position is likely to be conflated with a following alveolar consonant.

W2's coda /l/ production shows a different pattern: the overall estimate showed the tongue dorsum to be more fronted in coda /l/ compared to coda /d/ relative to the tongue tip difference between these two consonants. Consequently, tongue elongation was smaller in coda /l/ than in coda /d/. In contrast to the overall estimate, the tongue seemed to be more elongated in /l/ compared to /d/ in the part of the analysis window associated with the coda. In the rest of the analysis window, corresponding to the vowels in the carrier phrase and the target word, tongue was more elongated when the target word contained coda /d/ compared to coda /l/. That is, the results are inconclusive as the overall effects might indicate /l/-vocalisation, whereas a more detailed temporal analysis suggests that the analysis window needs to be smaller.

5. CONCLUSION

These data demonstrate the utility of tracking change in tongue elongation as a metric for lateral production. The tongue might be less elongated in coda /l/ compared to onset /l/, consistent with the lenition of the tongue tip gesture in coda /l/ observed in AusE. Future research on the articulatory characterisation of /l/ may include direct comparison of tongue elongation in onset and coda position to quantify /l/ vocalisation.

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