Which came first, chicken or egg? – Goals of production for lateral /l/ in Australian English

Jia Ying [1], Christopher Carignan[2]

Jason Shaw[3], Michael Proctor [4], Donald Derrick [5], Catherine Best [6]

[1,2,6] MARCS Institute, University of Western Sydney, Australia
[4]Macquarie University, Australia
[5] Institute of Language, Brain & Behaviour, University of Canterbury, New Zealand
[3]Yale University, USA

j.ying@westernsydney.edu.au, c.carignan@westernsydney.edu.au

Abstract

Articulatory data on /l/ have revealed that it involves multiple tongue movements in the mid-sagittal plane as well as para-sagittal lateralization. It is not clear which of the gestural movements occurs first. The present study replicated Sproat and Fujimura's (1993) study with a refined method in the mid-sagittal plane. In addition to this, we examined the relative timing of the mid-sagittal gestures and the para-sagittal gestures. We found the lateral formation reached its peak earlier than the tongue back retraction, suggesting that the formation of the lateral is the primary goal of /l/ production.

Keywords: Speech production, articulatory kinematics, dynamics of lateralization, electromagnetic articulography

1. Introduction

Articulatory data on lateral /l/ has revealed that there are multiple gestural targets in the mid-sagittal plane (Sproat & Fujimura, 1993; Browman & Goldstein, 1992) as well as formation of the lateral channel (Stone & Lundberg, 1996; Alwan, Narayanan & Haker, 1997; Lin, Beddor & Coetzee, 2014). These studies indirectly indicate that the production of /l/ in American English involves lateralization of the tongue. It is not clear from these studies: **Hypothesis (1)** Whether the two mid-sagittal gestural targets (tongue tip raising and tongue back retraction) are the consequence of the specification of [+lateral] (Sproat & Fujimura, 1993); or **Hypothesis (2)** Whether the formation of the lateral channel is the consequence of the mid-sagittal gestural targets (Browman and Goldstein, 1995). A more complete understanding of /l/ requires knowledge of articulation of both the mid-sagittal plane and of the formation of the lateral channel. We tested these two hypotheses through a vowel and syllable position manipulation. According to the first hypothesis, we predicted that the timing of mid-sagittal gestural targets would vary as a function of the preceding vowel while the formation of the lateral channel will be constant across vowels. According to the second hypothesis, we predicted that the timing of the mid-sagittal gestural targets would be consistent across vowels but the dynamics of the lateral channel formation would vary across vowel.

2. Method

We conducted a 3D electromagnetic articulography (EMA) study with mid- and para-sagittal sensor placement.

2.1. Participants and stimuli

Six mono-lingual Australian English speakers (3 females and 3 males, average age = 21) were recorded. The target laterals were elicited in two vowel contexts (/æ/ and /ɪ/) and in two contrastive syllable positions: onset laterals in a CVC.lVC frame, and coda lateral in a CVl.CVC frame (Table 1). Vowels /æ/ and /ɪ/ were chosen because of the different constraints that they place on the shape of the tongue preceding /l/ (Stone & Lundberg, 1996). The two syllable positions allow us to compare variation in the timing of mid-sagittal movements relative to para-sagittal dynamics.

Table 1: A list of target words.

Vowel	/æ/	/ɪ/
CVC.LVC	*tab.let* *cab.let*	*tib.let* *kib.let*
(C)VL.CVC	*tal.bot* *cal.bert* *al.bert*	*til.bert* *kil.bert* *il.bert*

2.2. Procedure

Three sensors (Figure 1) were affixed mid-sagitally to the tongue tip (TT), tongue middle (TM), and tongue back (TB); and two additional sensors were affixed para-sagitally to the sides of the tongue (parasagittal tongue left: PTL & para-sagittal tongue right: PTR).

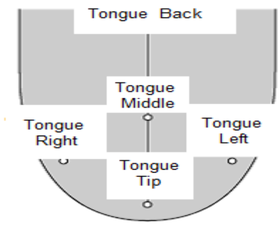

Figure 1. *Placement of tongue sensors*

2.4.1 Mid-sagittal Analysis

For the mid-sagittal analysis, we measured the delay between TT and TM (1), TT and TB (2):

$$TM\ Delay = TT\ Extremum - TM\ Extremum \quad (1)$$
$$TB\ Delay = TT\ Extremum - TB\ Extremum \quad (2)$$

The extremum is a point when the articulator is maximally constricted (corresponding to the minimum velocity signal during /l/ production). The TT and TM extrema were derived from the velocity of the *z*-dimension (i.e., corresponding to tongue raising), while the TB extremum was derived from the velocity of the *x*-dimension (i.e., corresponding to tongue body retraction). A positive value indicates that the TM/TB gestural target occurs earlier than the TT gestural target. A negative value indicates that the TT gestural target occurs earlier than that for TM/TB.

2.4.2 Para-sagittal Analysis

For the para-sagittal analysis, we computed a lateralization index to capture the degree to which the sides of the tongue are higher/lower than the mid-sagittal plane. In order to do this, we estimated a tongue blade location (between TT and TM) in the mid-sagittal plane by fitting a second-order polynomial to the *x* (horizontal) and *z* (vertical) dimensions of the mid-sagittal sensors. Then we located the intersection point between this polynomial and the horizontal dimension of the para-sagittal sensors (PTR and PTL). The *x*-, *y*-, *z*-values of this point represents the intersection of the mid-sagittal and coronal planes at the location of the para-sagittal sensors along the horizontal dimension. Then we then calculated the difference of the vertical position of this estimated blade sensor and the para-sagittal sensors (3):

$$\Delta\ Height = estimated\ tongue\ blade - PTL/PTR \quad (3)$$

We have only reported data from the dominant lateralization side (the side with the higher value) for each speaker. In order to identify the production goal, we extracted the gestural maxima of TM, TB and Δ Height. For TM and TB, the maximum is the time point associated with the minimum velocity in the lowering gesture (z dimension) and retraction gesture (x dimension), respectively. For Δ Height, the maximum is the time point associated with the greatest value in the lateralization index. Then we use this formula to measure the difference between the timing of the mid- and para-sagittal targets (4):

$$Relative\ timing\ difference = TM/TB - \Delta\ Height \quad (4)$$

A negative value indicates that the mid-sagittal gestural target (i.e., TM lowering/TB retraction) occurs first, while a positive value indicates that the para-sagittal gestural target occurs first.

3. Results

3.1 Mid-sagittal results

Our results from the TT-to-TM and TT-to-TB delay analyses replicated Sproat & Fujimura's (1993) study (Figure 2), though the TT-to-TB delay results were not statistically significant across both syllable positions. The delay in syllable-onset position was near zero or negative. This indicates that TT gestural target is reached just prior to the TM/TB gestural target, or is nearly synchronous. The delay in syllable-coda position was positive. This indicates that the TM/TB gestural target is reached prior to the TT gestural target. In addition, we also found that /l/ adjacent to /æ/ has longer duration than adjacent to /ɪ/.

3.2 Para-sagittal results

Our results from the lateralization interval indicate that the lateral target occurs earlier than the lowering/retraction target, or is nearly synchronous in both syllable positions. Most of the values are either positive or close to zero. The preceding vowel and syllable position do not have an effect on the timing, except for syllable-onset /ɪ/, for which the difference is even more pronounced (Figure 3).

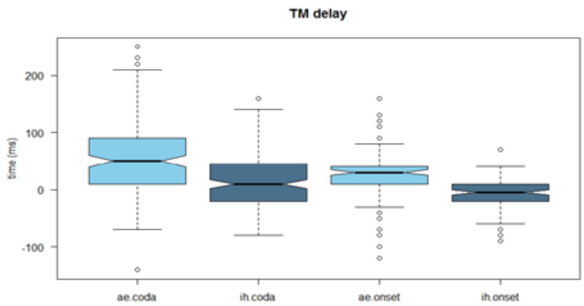

Figure 2. *The TT-to-TM delay of /l/ words in onset and coda position in /æ/ and /ɪ/ context.*

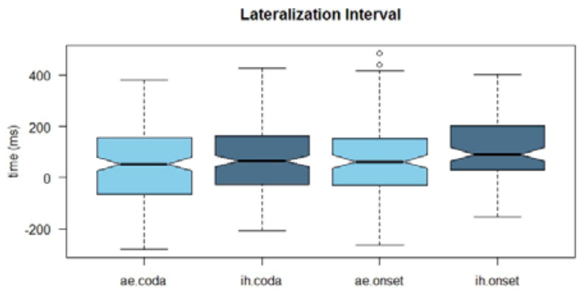

Figure 3. *The lateralization interval of /æ/ and /ɪ/ across syllable position.*

4. Discussion and conclusion

For the mid-sagittal analysis, our study replicated Sproat & Fujimura's study (1993) in that we observed multiple gestures in the mid-sagittal plane for both clear [l] and dark [ɫ]. The difference between onset and coda position was significant and consistent across vowel environments. For the para-sagittal analysis, our results suggested that the preceding vowel and syllable position do not have significant effects on lateralization interval. Though when /l/ is in onset position, the lateralization interval began slightly earlier in /ɪ/ than in /æ/, the result is not statistically significant. The timing of mid-sagittal gestural targets varied as a function of the preceding vowel, while the formation of the lateral channel remains consistent across vowels. Our explanation is that in order to maintain consistent tongue lateralization duration across different vowels, the mid-sagittal gestural targets begin earlier in /æl/ than in /ɪl/. We conclude that the data support the hypothesis that formation of a lateral channel is the goal of /l/ production that TT and TM gestures are coordinated to achieve.

5. Selected references

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