The effect of vowel length on CVC syllables in Australian English

Louise Ratko, Michael Proctor and Felicity Cox

Onset and coda consonants display different patterns of articulatory organisation with respect to the syllable nucleus: onsets share a closer timing relationship with the syllable nucleus than codas [2, 4]. Temporal and spatial properties of coda consonant gestures are also reduced and more variable in their realisation than those of onset consonants [2]. Articulatory organisation within the syllable is also affected by phonological vowel length, however this process is still not clearly understood. In Estonian, German and Slovak, onsets and codas in syllables with long vowels have longer gestural durations and are produced with greater displacement of the articulators than onsets and codas produced adjacent to short vowels [1, 5, 6, 7]. Australian English (AusE) provides an interesting test case for studying the effect of vowel length on articulatory organisation of CVC syllables due to its complex vowel length system. In AusE, /ɐː-ɐ/ share overlapping spectral qualities and are differentiated primarily by vowel duration [3]. Conversely, /iː-ɪ/ are differentiated by vowel duration and marginally by spectral quality [3]. Electromagnetic articulography (EMA) was used to investigate realisation of onset and coda consonants in pVp and pV:p syllables, focusing on vowel pairs /iː-ɪ/ (*beat-bit*) and /ɐː-ɐ/ (*cart-cut*).

Methods: EMA data was collected from 9 AusE speakers (5 males). Target items were embedded in one of two carrier phrases. For the high-front vowel pair /iː-ɪ/, the carrier contained low vowels *Far pVp heart* [fɐː pVp hɐːt], and for /ɐː-ɐ/, the carrier contained high vowels *Fee pVp heat* [fiː pVp hiːt]. For each target item, 1) onset consonant (C_1), 2) vowel (V) and 3) coda consonant (C_2) gestures were analysed. Gestural duration and gestural displacement were calculated as shown in Figure 1. Measurements were based on the lower lip (LL) sensor for C_1 and C_2, and the tongue dorsum (TD) sensor for vowel gestures. Gestural duration spanned from gesture onset to gesture offset (Fig. 1). Gestural displacement was calculated as the Euclidean displacement during gesture formation (movement towards the gestural target) + Euclidean displacement during gesture release (movement away from the gestural target; Fig. 1).

Results: Linear mixed effects models were constructed with the following equation: Dependent variable ~ V length (Long = 0) × V pair (high-front = 0) + (1 + V length | spkr) + (1+ V pair | spkr). The total gesture duration of long /iː/ and /ɐː/ was 64.0 ms longer than their short equivalents /ɪ, ɐ/ (p<.001; Fig. 3). There was no significant interaction between V length × V pair (p =. 521). The duration of C_1 preceding long Vs was 11.6 ms longer than for short Vs (p=.018; Fig. 2). For C_1 there was no significant interaction between V length × V pair (p =. 321).

The total duration of C_2 was unaffected by preceding V length (p=.733; Fig. 3). The interaction between V length × V pair on C_2 duration was not significant (p=. 061).

The displacement of long Vs was 1.8 mm greater than their short equivalents (p<.001; Fig. 4). There was a significant interaction between V length × V pair (p =. 018) indicating that the difference in displacement was greater between /iː/ and /ɪ/ (2.6 mm) than between /ɐː/ and /ɐ/ (1.0 mm). LL displacement of C_1 gestures preceding long Vs was 0.6 mm greater than C_1 preceding short Vs (p=.003; Fig. 3). There was no significant interaction between V length × V pair (p =. 155).

The displacement of C_2 following long Vs was 0.9 mm greater than C_2 preceding short Vs (p<.001; Fig. 4). There was a significant interaction between V length × V pair (p<. 001), indicating that the difference in displacement was greater between C_2 following /iː/ and /ɪ/ (1.6 mm) than for C_2 following /ɐː/ and /ɐ/ (0.3 mm).

Discussion: Consistent with studies showing /iː-ɪ/ to be more spectrally dissimilar than /ɐː-ɐ/ [3] we found a greater difference in displacement between /iː/ and /ɪ/ than between /ɐː/ and /ɐ/ (Fig. 3). Consistent with prior research, onsets preceding long vowels had greater durations than onsets preceding short vowels [1, 5, 6, 7]. However, contrary to past research, vowel length did not impact coda duration [1, 5, 6, 7]. The results also support studies that have found onsets and codas flanking long vowels to have a greater spatial extent than onset and codas flanking short vowels [1, 6]. Furthermore, codas following /iː-ɪ/ had a greater pairwise difference in gestural displacement than coda consonants following /ɐː-ɐ/ (Fig. 4). This difference was not observed however for onset consonants (Fig. 2). These overall results highlight the role of the syllable in articulating vowel length contrasts in AusE. However, observed asymmetry between onset and coda consonants highlight how differences in CV versus VC coordination may lead to different realisations of vowel length contrasts in onset versus coda consonants.

References

[1] Beňuš, S. “Control of phonemic length contrast and speech rate in vocalic and consonantal syllable nuclei”, *JASA*, vol. 130, no. 4, pp. 2116-2127, 2011.

[2] Byrd, D. “Influences on articulatory timing in consonant sequences”, *JPHON*, vol 24, no. 2, pp. 209-244, 1996.

[3] Cox, F. “The acoustic characteristics of /hVd/ vowels in the speech of some Australian Teenagers”, *AJL*, vol. 26, pp. 147-179, 2006.

[4] Goldstein, L., & Fowler, C.“Articulatory phonology: A phonology for public language use”. *Phonetics & phonology in language comprehension & production*, Berlin: Mouton de Gruyter, pp. 159-207, 2003.

[5] Hertrich, I., & Ackermann, H. “Articulatory control of phonological vowel length contrasts: Kinematic analysis of labial gestures”, *JASA*, vol. 102, pp. 523–536, 1997.

[6] Hoole, P., Mooshammer, C., & Tillmann, H. “Kinematic analysis of vowel production in German”, *Proc. of ICSLP 94*, vol. 1, pp. 53–56, 1994.

[7] Türk, H., Lippus, P., & Šimko, J. “Context-dependent articulation of consonant gemination in Estonian”, *Lab. Phon*., vol. 8, no. 26, pp. 1–26, 2017

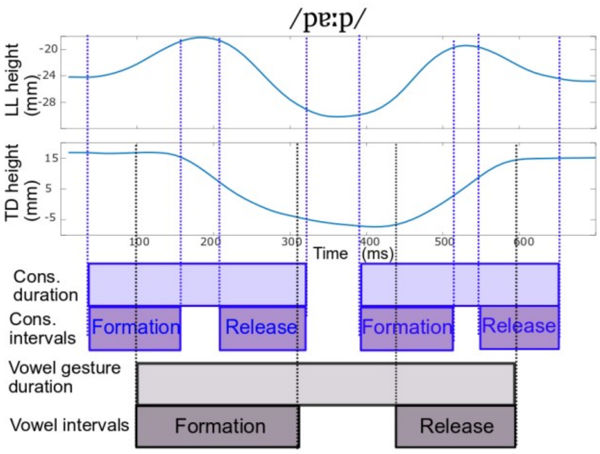

Figure 1. Articulatory measurements of syllables. *Token produced by W2. Top row: vertical LL height = vertical displacement of LL sensor. TD height = vertical displacement of tongue dorsum sensor. Vertical lines (left to right) denote key articulatory landmarks: C_1 Gesture and formation onset (blue), V onset (black), C_1 formation offset (blue), C_1 release onset (blue), V formation offset (black), C_1 gesture and release offset, C_2 gesture and formation onset,, V release onset, C_2 formation offset, C_2 release onset, V release offset, C_2 gesture and release offset.*

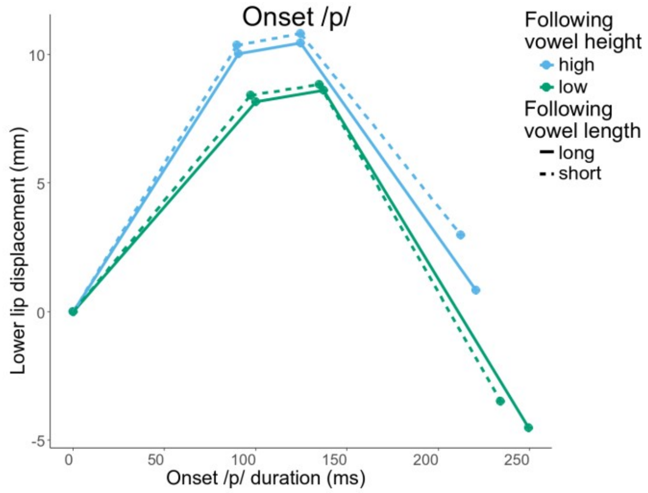

Figure 2. Displacement-time graph for onset /p/ gesture (C_1). *Lower lip sensor displacement from sensor position at onset of gesture Duration in ms*

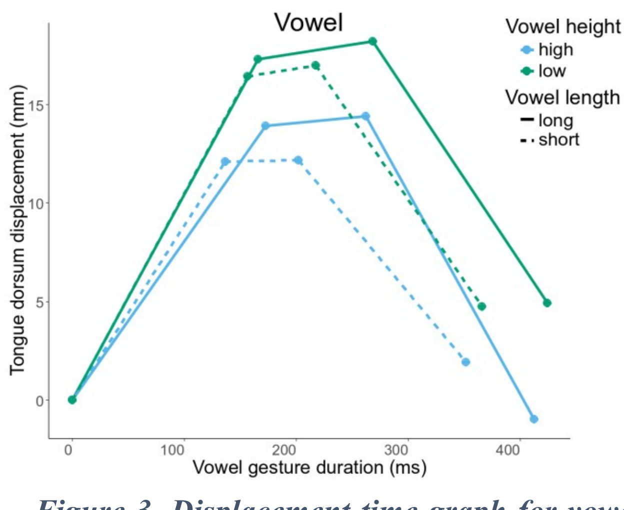

Figure 3. Displacement-time graph for vowel gesture. *Tongue dorsum sensor displacement from sensor position at onset of gesture. Duration in ms*

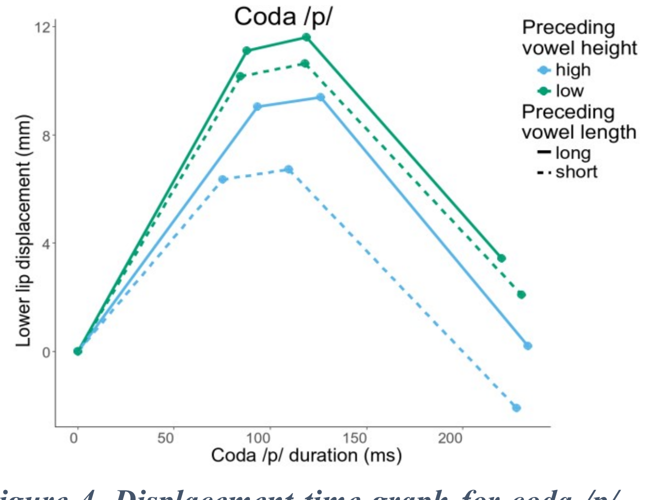

Figure 4. Displacement-time graph for coda /p/ gesture (C_2). *Lower lip sensor displacement from sensor position at onset of gesture. Duration in ms*