Articulatory characterisation of vowel length contrasts in Australian English

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Phonological vowel length in many Germanic languages is realised through both temporal and spectral contrasts [1, 2]. Acoustic studies have shown that short vowels are more centralised compared to their long equivalents [1, 2, 3], with proportionately shorter acoustic steady-states [2, 3, 4, 5], and longer transitions to surrounding consonants [6]. Many studies of English and German have explored the *acoustic* properties that characterise phonological vowel length contrasts [2, 4, 5], but fewer have explored the *articulatory* properties of long-short vowel pairs. In non-rhotic Australian English (AusE), the contrast between /ɐː/ '*Bart'* and /ɐ/ *'but'* is primarily durational, with acoustic studies finding a very close spectral correspondence between the two [6, 7, 8]. Other AusE long/short vowel contrasts, such as /iː/ '*beat'* - /ɪ/ '*bit'*, more closely resemble length distinctions found in American English and German, involving both temporal and spectral differences [2, 4, 5, 6, 7, 8]. AusE therefore offers an interesting test case for examining the articulatory implementation of different kinds of vowel length contrast.

This paper reports an Electromagnetic Articulography study of vowel length in AusE. We compare vertical and horizontal lingual displacement and articulatory kinematics in short vs. long vowels, and examine how these differ between vowels that have been shown acoustically to use both spectral and temporal contrastive cues (e.g. /iː-ɪ/) and those where differentiation is mainly restricted to the temporal domain (e.g. /ɐː-ɐ/).

Target vowels were elicited from 7 speakers of AusE (4 females, 3 males) in /pVp/, /tVt/ and /kVk/ monosyllables embedded in one of two carrier phrases to control for tongue movement. For the high vowel context /iː-ɪ/, the carrier contained low vowels 'Star CVC heart' [stɐː CVC hɐːt], and for the low vowel context /ɐː-ɐ/, the carrier contained high vowels 'See CVC heat' [siː CVC hiːt]. Participants produced each target word (in the relevant carrier) ten times in a randomised elicitation task. Here, we report on production in labial contexts only. Four landmarks were identified from tangential velocities of the rearmost lingual (dorsal) sensors in each vocalic trajectory [9], delineating three intervals: 1) constriction formation (CF), 2) gestural nucleus (GN), 3) constriction release (CR). For each vowel token, duration and displacement were calculated overall, and for each interval (1 to 3), for the dorsal sensor. Displacement trajectories were calculated from context origin (i.e. from the preceding to the following vowel in the carrier - /ɐː/ in 'star' for the /iː-ɪ/ tokens; /iː/ in 'see' for /ɐː-ɐ/ tokens). Mixed models were run with length (long/short) x height (high/low) as fixed factors and participant and repetition as random factors.

Short vowels /ɪ/ and /ɐ/ were both produced with less lingual displacement than their long equivalents /iː/ and /ɐː/ ($p<.001$; Fig. 1). There was an interaction between length and height ($p<.005$), suggesting the difference in displacement between /iː/ and /ɪ/ was greater than the difference in displacement between /ɐː/ and /ɐ/, consistent with the acoustic characterisation of /ɪ/ as more centralised with respect to /iː/, compared to the low-central vowel pair /ɐ-ɐː/.

The gestural durations for short vowels were 89.9% (sd = 6.42) of their long equivalents, with asymmetries in the articulatory realisations of short and long vowels (Fig. 2). Mean GN duration for short vowels /ɪ/ and /ɐ/ was shorter than for long vowels /iː/ and /ɐː/ ($p<.001$). Mean CR duration was longer for short vowels than for long vowels ($p<.001$). There was no significant difference in CF duration across short and long vowels and no interactions between length and height for any of the three intervals.

Our results are consistent with prior acoustic studies of AusE [6, 7, 8]; short vowels are articulatorily centralised and have proportionately shorter articulatory steady-states and longer transitions to following consonants than long vowels. The larger degree of centralisation of the short vowel in the high-front pair /iː-ɪ/ compared to /ɐː-ɐ/ suggests that centralisation may play a lesser role in distinguishing the low-central /ɐː-ɐ/ pair. Thus, AusE's /ɐː-ɐ/ contrast may be distinct from length contrasts in German, where all long-short vowel pairs exhibit equivalent degrees of lingual centralisation [4, 5]. Differences in the GN and CR duration between long/short vowel pairs suggest intrinsically different patterns of articulatory activity in AusE short vs long vowels. The relatively longer CR in short vowels might suggest a closer relationship between short vowels and their post-vocalic consonants than for long vowels in line with [4, 10].

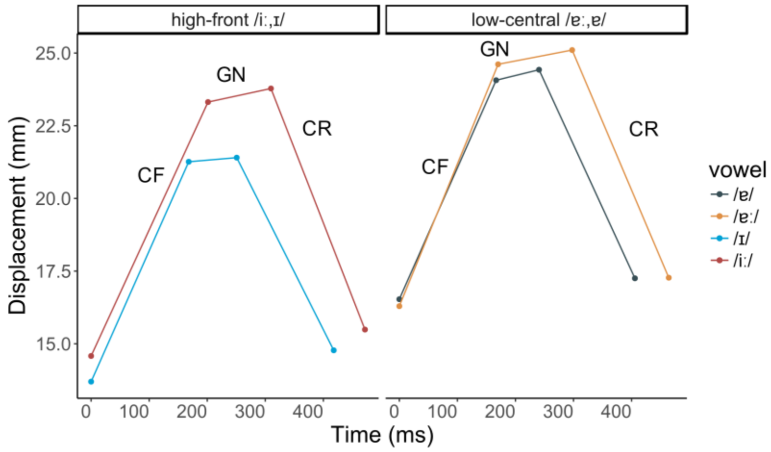

Figure 1: *Displacement of tongue dorsum sensor over time for constriction formation (CF), gestural nucleus (GN) and constriction release (CR). /iː-ɪ/ (left) and /ɐː-ɐ/ (right).*

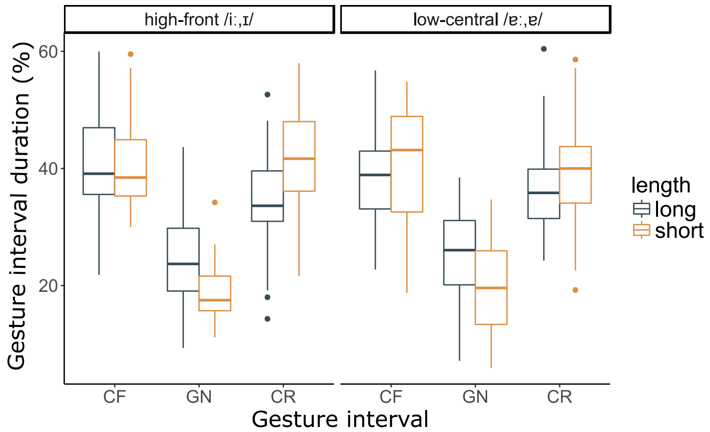

Figure 2: *Duration of constriction formation (CF), gestural nucleus (GN), constriction release (CR). All durations expressed as a proportion of total vowel duration.*

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