Asymmetries in the kinematics of Australian English vowel gestures

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Recent implementations of Articulatory Phonology have modelled consonant gestures using split-gesture dynamics [1, 2, 3, 4]. In these models, consonant gestures are decomposed into two independently controlled intervals: constriction formation (CF) and constriction release (CR) [2, 4]. Support for split-gesture models is based on observations that the kinematics of consonant constriction formation and release can be independently controlled [1, 2, 5]. To date, studies have focused on the split-gestural control of consonants, and it remains an open question as to whether split-gestural control also encompasses V gestures. In earlier work outside this framework, the German tense-lax vowel system has been modelled using split V dynamics [6, 7, 8]. The aim of this study is to investigate asymmetries in the kinematics of Australian English vowels which may suggest split-gestural control. Using electromagnetic articulography, we examine production of short and long vowels at two speech rates, compare patterns of articulation with those previously described for the German tense-lax contrasts, and discuss implications for gestural models of syllable organization.

Hypotheses

If formation and release phases of vowel gestures are independently controlled:

H1: Vowel length will impact the stiff-ratio [8, 9, 10] and/or duration of CF and CR differently
H2: Speech rate will impact the stiff-ratio and/or duration of CF and CR differently

If phonologically short vs. long vowels in Australian English are produced with similar kinematic differences to those observed in German [6, 7, 8]:

H3: the CF interval in short vowels will be truncated

Methods

Long /ɐː/ and short /ɐ/ (contrasted in '*bard'* and *'bud'*) were elicited from 6 female speakers of AusE in /pVp/ monosyllables. Target monosyllables were embedded in a carrier phrase: '*Fee pVp heat*' [fiː pVp hiːt], to control for tongue position prior to and following the target word. Participants produced each target ten times at two different speech rates: normal (stimulus presentation duration = 1500 ms), and fast (presentation duration = 750 ms). V gestures were located semi-automatically by tracking tangential velocity of a sensor attached to the midsagittal tongue dorsum (TD), using the *lp_findgest* algorithm in MVIEW [11].

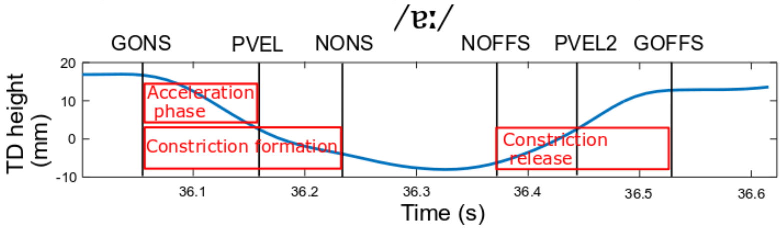

Figure 1. *Gestural intervals used to characterize vowel formation and release. Acceleration ratio = acceleration phase / constriction formation duration.*

Measurements (Fig. 1):

- **Stiff Ratio (SR)**: *peak TD velocity during interval / TD displacement from start to end of interval*
- **Acceleration Ratio (AR)**: *acceleration phase duration / total CF duration*.
  Acceleration phase = interval from gestural onset (GONS) to peak closure velocity (PVEL). A truncated interval will show a proportionately later peak velocity (AR >0.5) [6].

Results and discussion

We constructed linear mixed effects models in R [12] with the equation: Dependent Variable ~ Vowel length (LONG = 0, SHORT = 1) × Speech rate (NORMAL = 0, FAST = 1) {× Interval (CF = 0, CR = 1)} + (1 | speaker). CF was stiffer than CR ($\beta = -0.2$, $p = .006$; Fig. 2). The stiffness of CF was also more impacted by speech rate than the stiffness of CR ($\beta = -0.3$, $p = .014$). CF duration was not significantly different from CR duration ($p = .790$; Fig. 3). However, there was a significant interaction between Interval × Vowel length indicating that short Vs had shorter CFs but not shorter CRs than long Vs ($\beta = 27$ ms, $p = .049$; Fig. 3). Finally, acceleration phase ratio for short Vs was significantly greater than those of long Vs ($\beta = 0.3$, $p < .001$), indicating peak velocity occurred later in CF of short Vs than long Vs. However, average acceleration ratios for short Vs ($\mu = 0.5$) were not greater than 0.5.

Our findings reveal asymmetries in the kinematics of CF and CR intervals under changes to speech rate for vowels differing in length. Short Vs were characterized by proportionately later peak velocities (greater acceleration ratios) than long Vs; however, short V acceleration ratios were still ≥ 0.5, which suggests that contrary to results found for tense/lax Vs in German [6], short CFs are not truncated in AusE. Speech rate impacted CF stiffness more than CR stiffness, while vowel length impacted CF but not CR duration, suggesting that, similar to consonant gestures, vowel gestures may also exhibit split-gestural control [10]. Further investigation is required to better understand how vowel length differences are specified and realized in Australian English, and how vowel gestures interact with other components in the syllable at different speech rates.

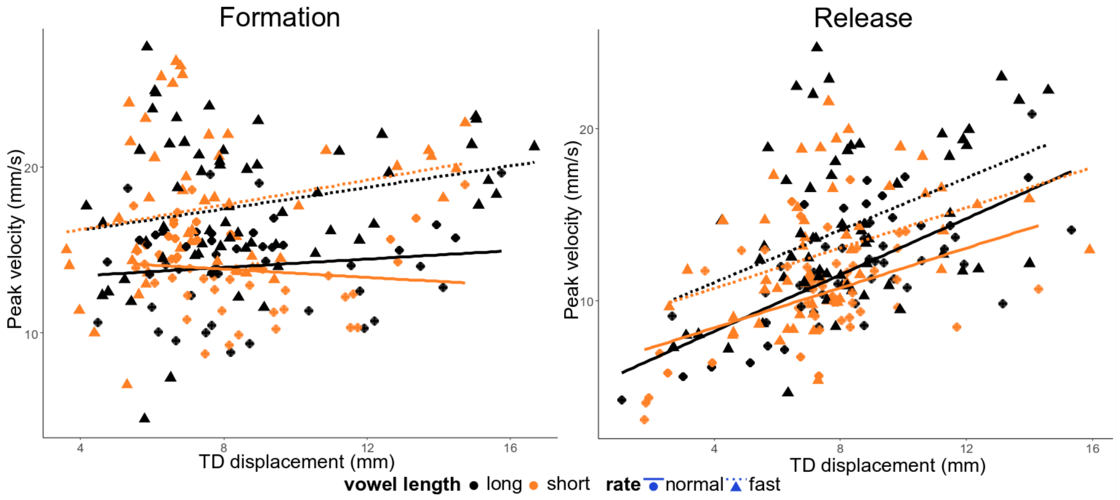

***Figure 2**. Peak dorsal velocity vs. displacement in formation (left) and release (right) phases of vowel gestures produced at two different speech rates. Regression lines computed separately for short (orange) and long (black) vowels, and for normal rate (circle, full line) and fast rate (triangle, dashed line).*

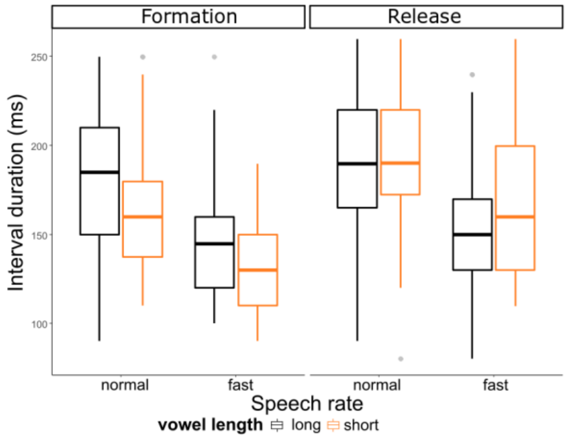

***Figure 3.** Constriction formation and constriction release durations for long and short vowels by speech rate.*

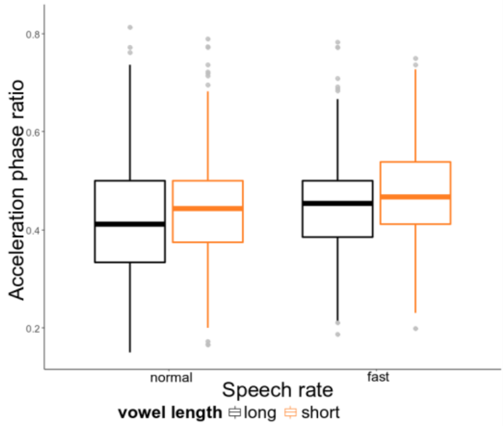

***Figure 4.** Acceleration phase ratios for long and short vowel formation by speech rate. Higher acceleration phase ratios indicate more truncated formations.*

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