Asymmetries in English Liquid Production and Vowel Interactions

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Understanding the controlled articulatory properties of liquid consonants in English has posed challenges. While it is generally accepted that English liquids /l/ and /ɹ/ are complex, involving anterior and posterior lingual constrictions (see Proctor 2009 for a review), questions about their precise articulatory goals remain. For example, several distinct tongue shapes have been identified for [ɹ], varying across speakers (Zhaoyan et al. 2003). The execution of liquids' articulation also varies with syllable context, with the formation of liquids' component constrictions coordinated differently in onsets versus codas (e.g., Sproat & Fujimura 1993; Gick et al. 2006; Campbell et al. 2010). Also, the phonotactics of /l/ and /ɹ/ differ in various ways. One notable difference is that fewer vowel distinctions are attested before coda /ɹ/ than coda /l/, and vowel contrasts are further reduced when followed by a liquid in a complex coda (Hammond 1999). In this paper, we use new articulatory data and methods of analysis to examine the production of English liquids, with focus on their controlled articulations and how they give rise to differences in vowel-rhotic and vowel-lateral phonotactics.

We report on a real-time MRI (rtMRI) study of the dynamical production of liquids in General American English (GAE). GAE is typified by the standard rhotic English varieties spoken in much of the midwestern United States. The rtMRI technique provides more global views of the vocal tract than many other sensing techniques (Fig. 1), and at sufficiently high frame rates to examine the coordination of speech articulators (Narayanan et al. 2004; Bresch et al. 2008). It has been successfully applied to investigations of the goals of speech production at different levels of phonological organization, including articulator coordination in speech sounds involving multiple articulators (Byrd et al. 2009; Proctor et al. 2013).

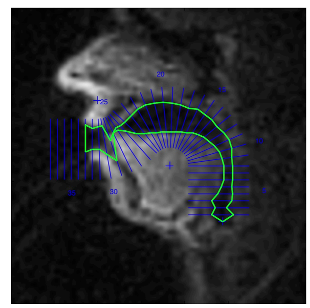

Figure 1: rtMRI frame displaying air-tissue boundaries in midsagittal vocal tract during GAE [l] (Proctor et al. 2010)

We investigate two hypotheses: (i) /ɹ/ in GAE is defined by a tongue body gesture with stronger blending parameters than that of the lateral, which results in its exerting a more global influence over tongue shaping and constriction location than /l/ (on blending parameters, see Saltzman & Munhall 1989); and (ii) /l/ is produced with more variance in timing and place of tongue body articulation than the English rhotic. Specifically, under these hypotheses, we predict that [ɹ] will show less variance than [l] in tongue body center of gravity (CoG) across different vocalic contexts and syllable positions, and it will show less variance overall in the mean midsagittal lingual deformation in transitions between vowels and liquids. These intrinsic articulatory differences between the two liquids give rise to both the more restricted distribution of the rhotic, and the greater degree of position-dependent allophony exhibited by laterals in GAE, such as coda darkening.

We conducted a speech production study with four speakers of GAE using rtMRI. The technique used for this investigation captures images of the midsagittal plane of the entire vocal tract at 23.2 frames/sec. Participants produced liquids in monosyllabic words in simple and complex syllable onsets and codas in all phonotactically well-formed vocalic contexts. Where possible, real words of English were used (e.g. *lip*, *flip*, *pill*, *film, rob*, *prop*, *bar*, *barb*). To minimize coarticulatory interference, only labial consonants (other than the target liquid) were used in stimuli, where possible. In some words with complex codas, coronal obstruents were elicited after the target liquid due to phonotactic restrictions (e.g. *peeled*).

Five repetitions of each word were captured from each speaker. Participants also demonstrated each of their vowels in monosyllabic words containing only labial consonants, enabling comparison of intrinsic tongue shapes for vowels with those of the same vowels produced in the context of liquids. For each segment of interest, the sequence of image frames was identified, capturing target articulations of the liquid consonant and the adjacent vowel. Tongue edges were automatically located (Proctor et al. 2010), and manually corrected where necessary, to produce a series of lingual outlines tracking the change in articulation from onset liquids into following vowels, and from vowels into coda liquids. Lingual displacement was tracked by calculating CoG of the midsagittal lingual outlines, and changes in articulation in different regions of the tongue (tip, blade, body, root) were quantified in terms of lingual displacement along regions of the semipolar grid used to locate outlines.

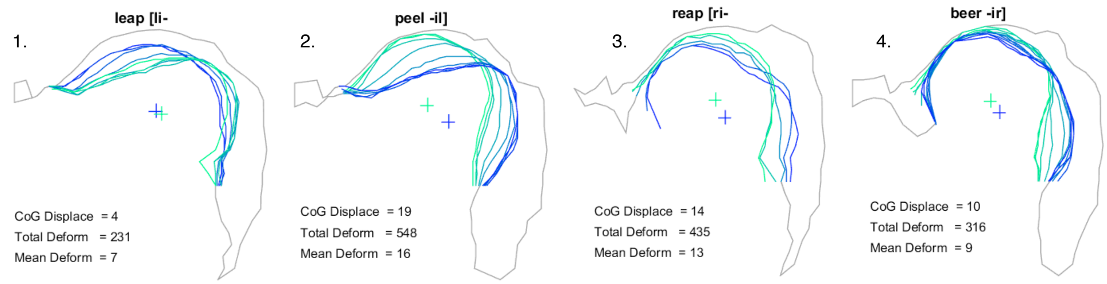

Figure 2: Comparison of lateral and rhotic production in onset and coda by a female speaker of GAE.

Tongue edge series and measurements for this study are illustrated in Figure 2, with liquids in the context of [i]. Midsagittal tongue positions captured at successive 23.2 ms intervals are superimposed to show the time-course of production from onset consonants (blue lines) into vocalic nuclei (green lines) in panels 1 and 3, and from nuclear vowels (green) into coda consonants (blue) in panels 2 and 4. Although individual speakers in our study produce rhotics characterized by qualitatively different midsagittal forms, our preliminary results indicate that the variant postures are united in that they all constrain global tongue shaping more consistently across different positions in the syllable (mean radial lingual deformation, from liquid-to-vowel, and vowel-to-liquid, as assessed over all vowels, individual productions and vowels may vary). Lateral production, in contrast, involves greater spatial and temporal independence between coronal and dorsal components: achievement of tongue-tip and tongue body constriction targets is not as synchronous as in rhotics, and tongue body constriction location, as indicated by CoG, differs more between onsets and codas, compared to rhotics.

Our preliminary results shed light not only on the nature of articulatory control in GAE rhotics versus laterals, but also on the reduction of vocalic contrasts before coda /ɹ/. For example, while tense/lax vowel contrasts occur before coda /l/ in word pairs such as *feel*/*fill*, *fail*/*fell*, before coda /ɹ/ these contrasts are absent, reducing to *fear*, *fair*. Tense/lax vowel pairs are produced in relatively close proximity to one another. The stricter articulatory dictates that we have found for /ɹ/ in comparison to /l/ make these finer vocalic distinctions more difficult to produce before coda /ɹ/, and hence more prone to neutralization.

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