Asymmetries in English Liquid Production and Vowel Interactions

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Liquid Phonotactics

Vowel contrasts before a liquid consonant:
- Differences in vowel-lateral and vowel-rhotic phonotactics in General American English (GAE)[1,2,3]
  - Tense/lax vowel contrasts before coda /l/ but not coda /ɹ/
    - E.g.: VI peel [i] vs peel [ɹ]
    - V contrasts reduced further before liquids in a complex coda, but more drastically before /ɹ/
  - No restrictions on V contrasts following onset liquids

Prior Work: Articulation & Representation

English liquids comprise two lingual articulations:
- Laterals: tongue tip closure, tongue body retraction[4,5,6]
- Rhotics: tongue body raising, tongue root retraction[7,8]

Constriction timing varies by syllable position[9]:
- Onset: Synchronous formation of constrictions
- Coda: Vowel-like lingual retraction precedes consonant-like lingual raising

Research Aims

- Gain better understanding of production goals of laterals and rhotics in GAE
- Use new articulatory data and methods of analysis
- Bring insight to basis for phonotactic asymmetries

Results

Vowel targets:
- Uncoarticulated lingual posture for 4 vowels
- Labial __ Labial context
- Deep [i], peep [ɹ], boom [u], go-[u]

Data Analysis

Articulatory Landmarks
- Vocalic, consonantal targets identified in each utterance
- V: maximally stable dorsum at target posture
- L: max. elongation (TT → TB) in cons. acoustic interval
- R: max. stability posture in cons. acoustic interval

Vocal tract outline displays
- Superimposed outlines reveal changes in tongue shape

Hypothesis

GAE /ɹ/ has a tongue body gesture with stronger blending parameters than that of /l/.

Predictions:
1. [ɹ] will show less variance than /l/ in Center of Gravity (CoG) across different
   - Vowel contexts and syllable positions
2. CoG of vowels more affected in context of
   - Coda /ɹ/ than coda /l/

Real-time MRI Study

Real-time Magnetic Resonance Imaging (rtMRI)[6,7,8]
- Entire vocal tract imaged in midsagittal plane
- 68 x 68 pixel spatial res.; 200 x 200 mm field of view
- New complete image acquired every 80 ms, reconstructed as 23.2 f.s. video[11]
- Synchronized noise-reduced speech audio recording[12]

Subjects: Three GAE speakers: two female, one male
Stimuli: Monosyllabic words containing a lateral/rhotic
- In onset; in coda; attested V contrasts, other Cs labial
  - Ex: peel [i] vs. bar [ɹ]
- Vowel contrasts in Labial __ Labial context
  - Ex: beep [i], boom [u]

Phonotactics

Phonotactics[13,14]
- No restrictions on V contrasts following onset liquids
- Differences in vowel-lateral and vowel-rhotic phonotactics in General American English (GAE)[1,2,3]
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Coarticulation

Coarticulation according to gestural strength parameters
- Like lingual raising
- Coda effect: Closer proximity of target achievement for liquids as opposed to pre-/l/

Vowel contrasts before coda /ɹ/ than coda /l/
- dCoG: Mean Euclidean distance for V targets in pre-liquid context compared to uncoarticulated target
  - dCoG /ɹ/ vs. /l/ (= 12.3) > dCoG /ɹ/ vs. /l/ (= 7.4)

Center of Gravity (CoG)
- Cartesian centroid of polygon defined by midsagittal lingual outline
- Motivated by variation in tongue shape for liquids across speakers, especially for rhotics

Representation of liquids in Articulatory Phonology[10,11]
- Gestures are dynamic phonological units specified for
  - Goal articulatory state: Articulators; Blending strength
- Articulatory blending[12]
- Goal articulatory states blended by weighted averaging according to gestural strength parameters

Degree of Articulatory Constraint (DAC) Model[12]
- Liquids receive high DAC values, resisting V-to-C coarticulation and triggering C-to-V coarticulation

Fig 4. Lateral onsets C targets across V contexts
Fig 5. Lateral codas C targets across V contexts
Fig 6. Rhotic onsets C targets across V contexts
Fig 7. Rhotic codas C targets across V contexts

Results

Illustrated for subject F1

Consonant targets: CoG marked by ‘•’
- Illustrated for subject F1

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Prediction 1 supported for F1:
- CoG for [ɹ] shows less variance than for /l/:
  - Across vocalic contexts – more consistent CoG in fig. 4 vs. 6 and in 5 vs. 7
  - Across syllable positions – more consistent CoG across figs. 6 and 7 than across figs. 4 and 5

Uncoarticulated lingual posture for 4 vowels
Labial __ Labial context
Deep [i], peep [ɹ], boom [u], go-[u]

Pre-/l/ Vs are less displaced by coarticulation, compared to uncoarticulated posture, than pre-/ɹ/
Pre-/ɹ/ Vs are more constrained around mean CoG
Point to support for prediction 2
Future analysis
- Quantitative approaches for these kinds of data are still in development
- Integrate spatial/temporal effects
- SS ANOVAs[24] and ROI[25] analyses planned

Discussion

Articulatory control in liquids
- rtMRI data point to a difference in coarticulatory strength in GAE laterals versus rhotics
- Consistent with stronger blending parameters for tongue body gesture in /ɹ/ than /l/
- Open questions:
  - Is the difference intrinsic to the articulation of these liquids or language specific?
  - Does the difference hold for other liquids or language specific?

Phonotactic asymmetries
- Difference in gestural strength parameters for /ɹ/ vs. /l/ gives rise to
  - Neutralization of tense/lax V contrasts before coda /ɹ/
- Coda effect: Closer proximity of target achievement for tongue body gesture in V and coda liquid vs. onset
Future: Analysis of intervocalic liquids and complex codas
References