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/
  Exx: **Vl** ***peel* [i]** vs.**pill [ɪ]**
  Vɹ ***peer*** (no [i]/[ɪ] contrast)
- V contrasts reduced further before liquids in a complex coda, but more drastically before /ɹ/
- No restrictions on V contrasts following onset liquids

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***

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

Representing liquids in Articulatory Phonology[10,11]

- **Gestures** are dynamic phonological units specified for
  - Goal articulatory state; Articulators; Blending strength

Gestural blending[12]

- Goal articulatory states blended by weighted averaging according to gestural strength parameters

Degree of Articulatory Constraint (DAC) Model[13]

- Liquids receive high DAC values, resisting V-to-C coarticulation and triggering C-to-V coarticulation

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
   - **vocalic 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):[14]

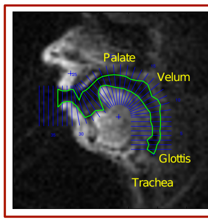
- Entire vocal tract imaged in midsagittal plane
- 68 x 68 pixel spatial res.; 200 x 200 mm field of view
- New complete image acquired every 80 ms, reconstructed as 23.2 f.p.s. video[15]
- Synchronized noise-reduced speech audio recording[16]

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
  Exx: ***peel* /-il/, *bar* /-ɑɹ/**
- Vowel contrasts in Labial __ Labial context
  Exx: ***beep* [i], *boom* [u]**

Data Analysis



- MR image captured during articulation of [ɹ]
- **Green lines: Vocal tract outline** generated by semi-automatic identification of air-tissue boundaries[17]
- **Blue lines: Analysis grid**

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 rhotic posture in cons. acoustic interval

Vocal tract outline displays

- Superimposed outlines reveal changes in tongue shape

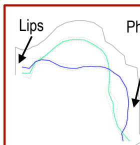


Fig. 1 ***peel***

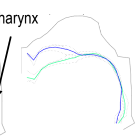


Fig. 2 ***pal***

V target (green) and ***C target*** (blue) (mean of 3 utterances)

Fig. 3 ***peel***

Time series from V target to C target

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

Results

- Illustrated for subject F1

Consonant targets: CoG marked by '+'

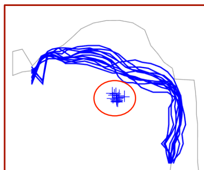


Fig 4. Lateral onsets
C targets across V contexts

Fig 5. Lateral codas
C targets across V contexts

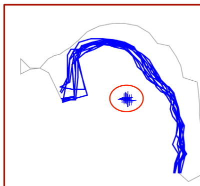


Fig 6. Rhotic onsets
C targets across V contexts

Fig 7. Rhotic codas
C targets across V contexts

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

Results

Vowel targets:

Fig 8. Uncoarticulated V targets

- Uncoarticulated lingual posture for 4 vowels
- Labial __ Labial context
- beep [i], pep [ɛ], boom [u], bob [ɑ]

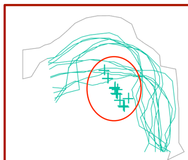


Fig 9. V targets before coda /l/ (3 reps)

Fig 10. V targets before coda /ɹ/ (3 reps)

- **Vowel CoGs cluster closer before coda /ɹ/ than coda /l/**
  - **dCoG**: Mean Euclidean distance for V targets in pre-liquid context compared to uncoarticulated target
  - **dCoG _ /ɹ/ (= 12.3) > dCoG _ /l/ (= 7.4)**

Cross-speaker comparison

- Three reps pooled across 3 speakers

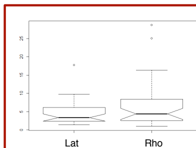


Fig 11. Displacement from uncoarticulated target (mm)

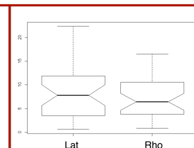


Fig 12. Displacement from mean CoG (mm)

- **Pre-/l/ Vs are less displaced by coarticulation**, compared to uncoarticulated posture, than pre-/ɹ/ Vs
- **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 ANOVA[18] and ROI[19] 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 rhotics and laterals?

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

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