2pSC16

Quantifying labial, palatal, and pharyngeal contributions to third formant lowering in American English /ɹ/

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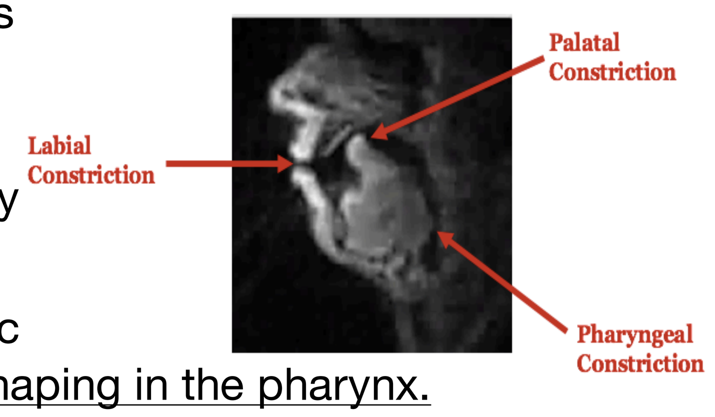
CONSTRICTIONS AND THE RHOTIC F3

Substantial variability observed in the implementation of the three articulatory gestures involved in English /ɹ/ production ([1 - 3]).

- Despite this variability, first three formants remain relatively stable (e.g, [4],[5]).



Contributions of individual constrictions to acoustic signal to F3 lowering remain largely unknown.

- Most methods for acquisition of kinematic speech data unable to measure airway shaping in the pharynx.
- Requires simultaneous articulatory and acoustic data in quantities sufficient to evaluate effects of intraspeaker variation.

Real-time MRI of the moving vocal tract provides dynamic articulatory information along the entire mid-sagittal plane and simultaneous audio.

Objectives of Present Study:

1. Quantify individual constriction contributions to F3 lowering.
2. Explore effect of articulatory variation on each gesture's contribution.

METHODS

Real-time MRI capture of four speakers (2 male, 2 female) reading sentences in the USC-TIMIT corpus [7].

- Word-initial and word-final /ɹ/ selected for analysis (135-200 per speaker).

Articulatory Analysis

Time of maximal constriction for each gesture found using Region of Interest technique [8] (*Figure 1*).

- Defined as velocity minimum closest to manually identified pixel intensity maximum [9].

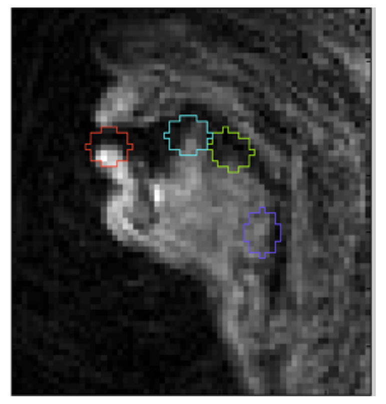


Figure 1: Vocal Tract with ROI regions overlaid (Red = Labial, Blue and Green = Palatal, Purple = Pharyngeal)

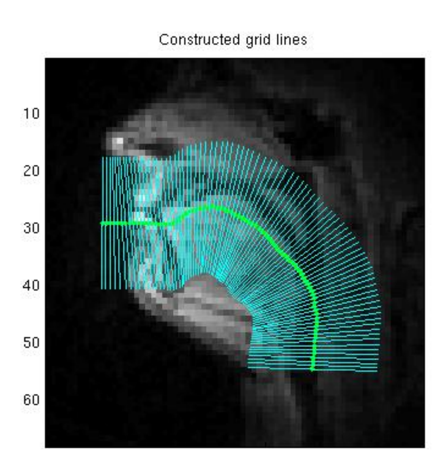


Figure 2: Grid lines used to measure length and location of constrictions

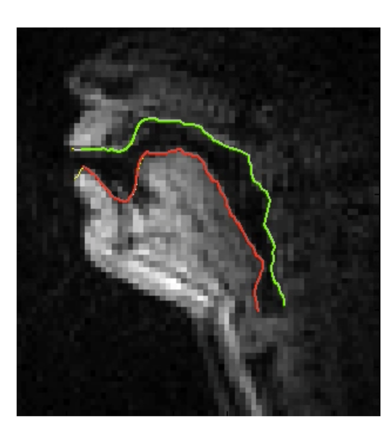


Figure 3: Upper and lower air-tissue boundaries

Minimum aperture, constriction location, and constriction length analyzed using air-tissue boundary segmentation [9] (*Figures 2 & 3*).

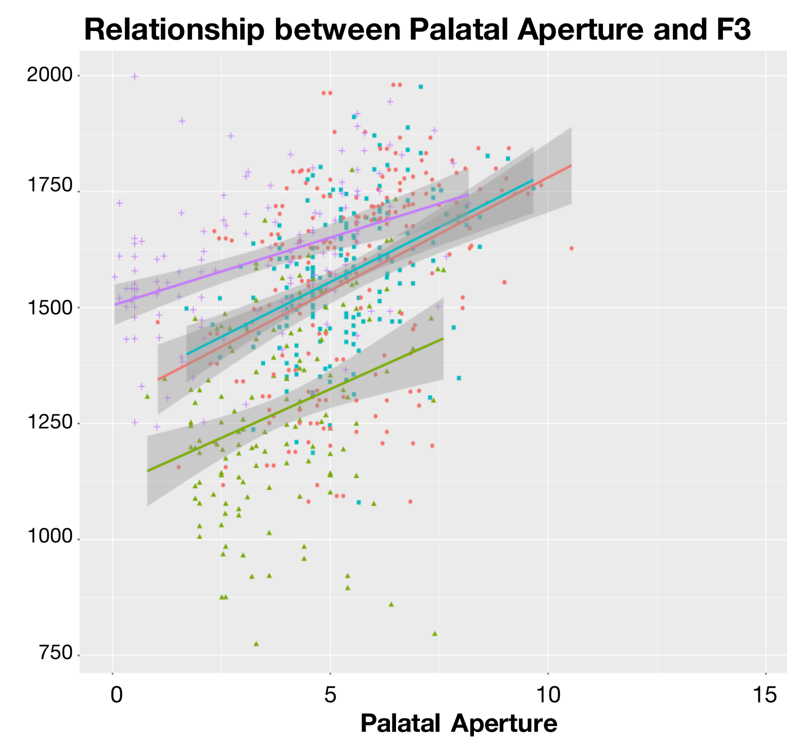
- Minimum aperture = Smallest measured distance between upper and lower air-tissue boundaries within designated region of vocal tract.
- Location = Grid line where minimum aperture measured.
- Length = Number of adjacent gridlines with aperture within 1.5 mm of minimum.

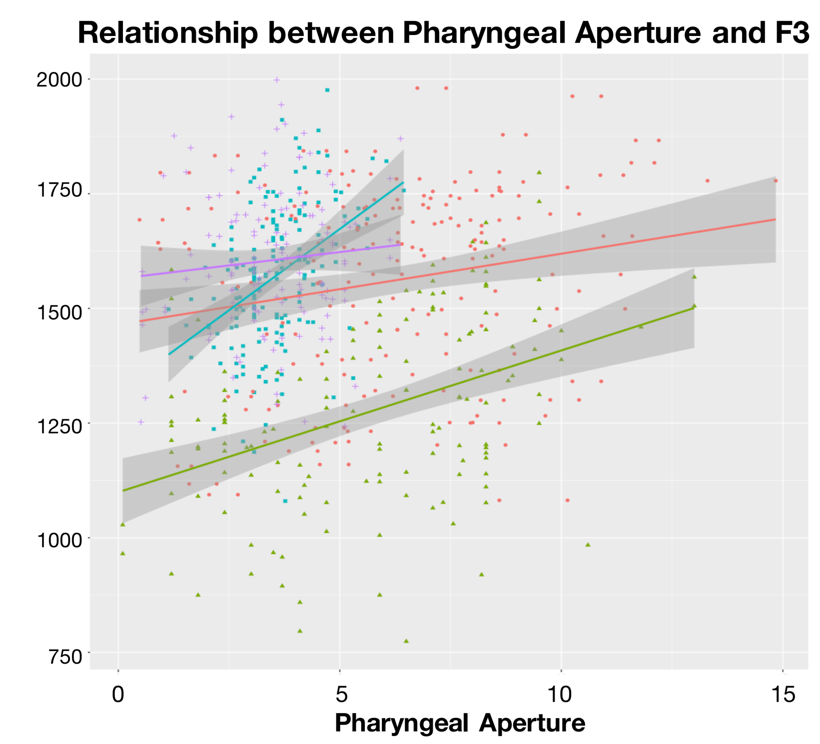
Acoustic Analysis

Acoustic data taken from simultaneous audio recordings of real-time MRI sessions.

- F1-F4 values extracted at time of maximal constriction for each gesture.

EFFECT OF APERTURE ON F3





- Palatal and labial aperture significant predictors of F3 for all speakers (all $p < 0.0001$).
- Pharyngeal aperture significant predictor of F3 for 3 speakers.
- Comparison of 95% confidence intervals for analyses of palatal and pharyngeal aperture revealed a difference in effect size for speaker AK.

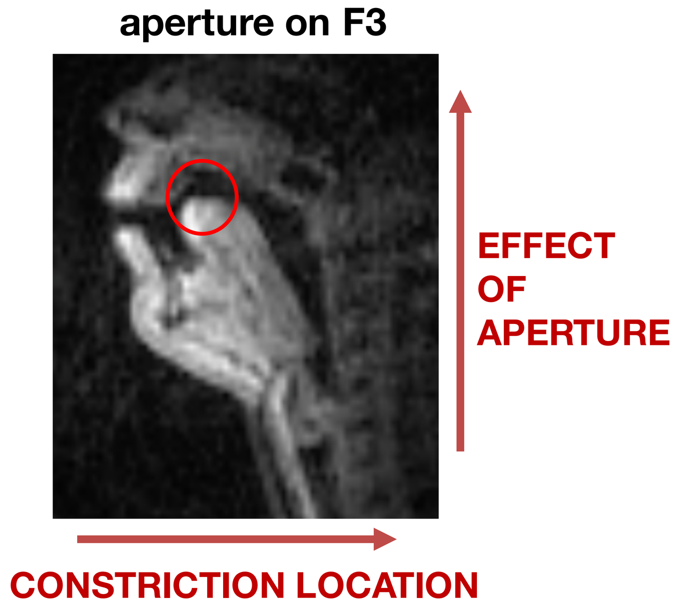
	MM	AK	CH	AL
Palatal Aperture	25.9*** (5.1)	80*** (9.1)	60.3*** (8.8)	53.6*** (11.27)
Phar. Aperture	8.1 (10.1)	15.7** (5.7)	71.7*** (11.49)	31.3*** (5.7)

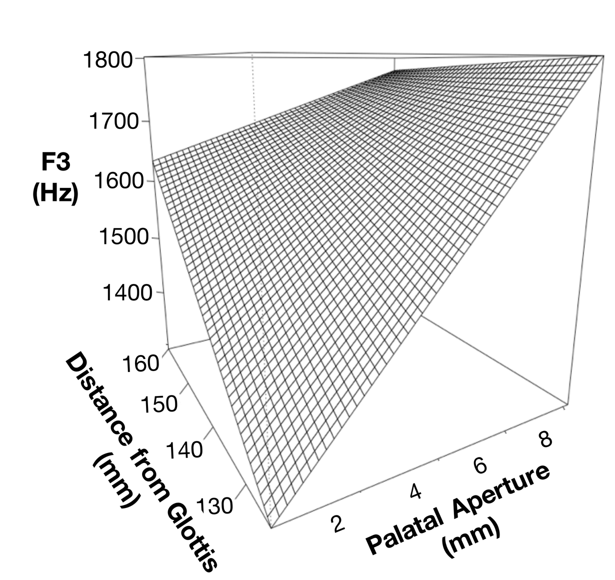
EFFECT OF LENGTH & LOCATION ON F3

Different speakers exhibited different patterns with respect to the relationship between F3, the length and location of constrictions, and constriction aperture.

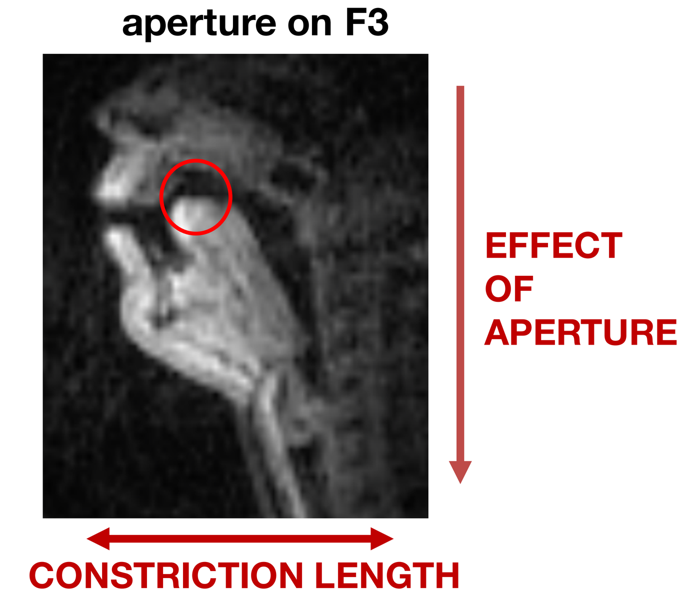
- Example: interactions between palatal constriction length, location, and aperture only observed for speaker MM.

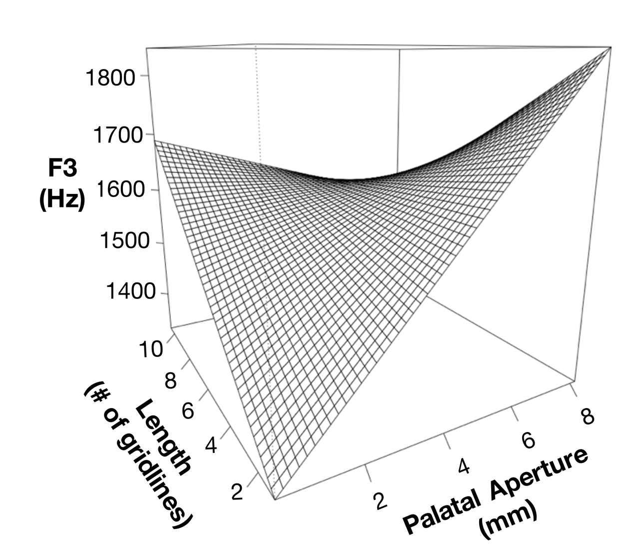
Negative interaction between palatal constriction location and effect on aperture on F3



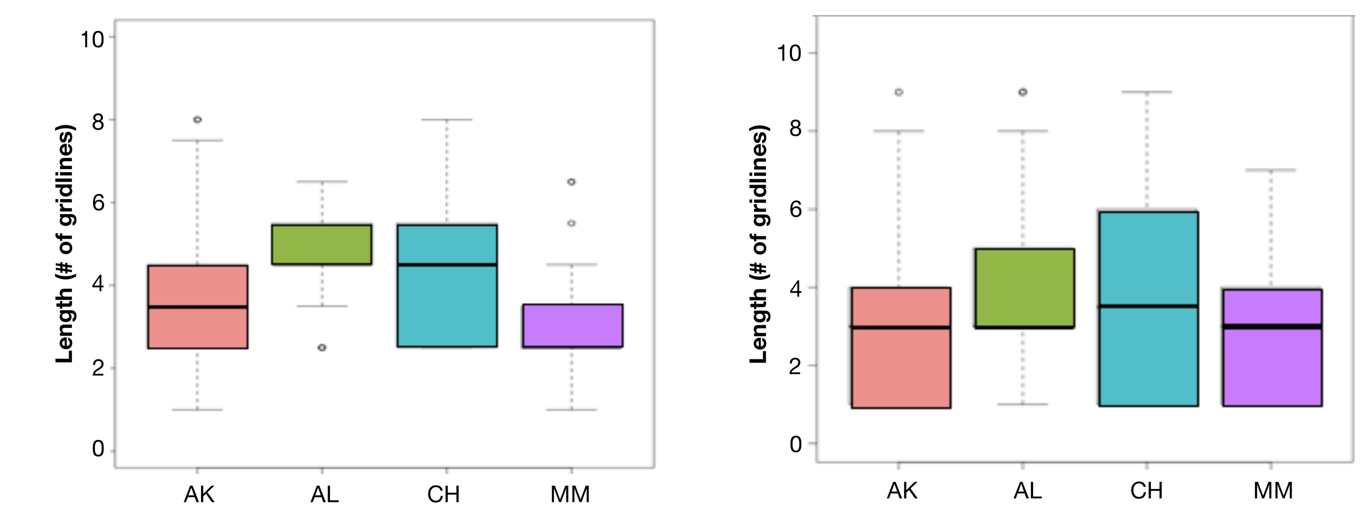


Negative interaction between palatal constriction length and effect of aperture on F3





INDIVIDUAL DIFFERENCES IN CONSTRICTION LENGTH AND LOCATION



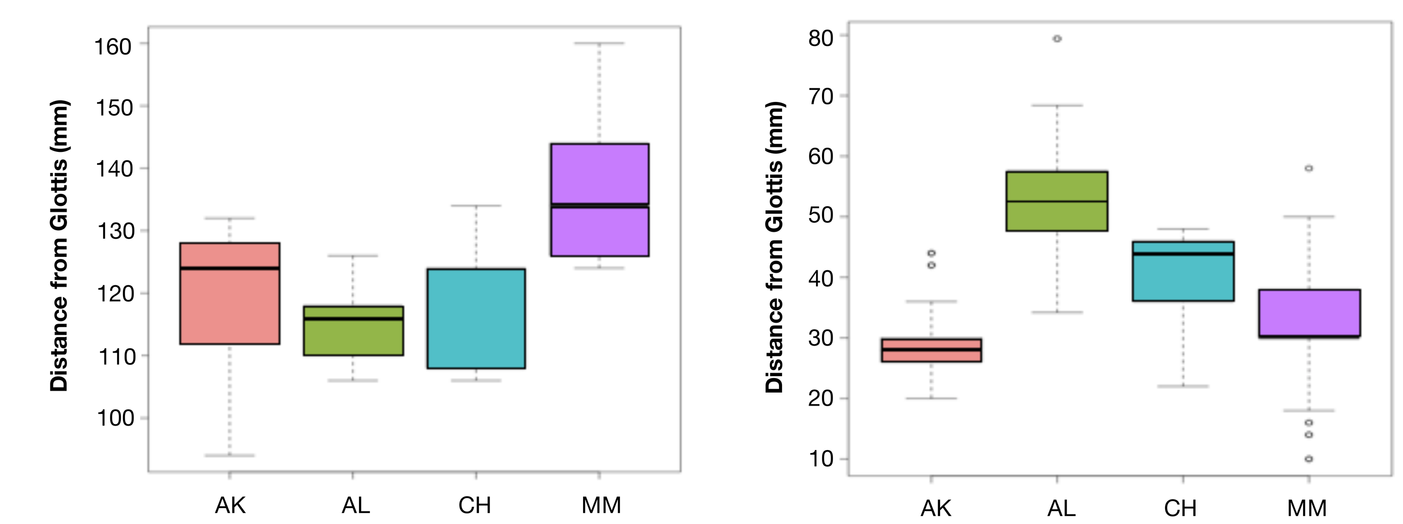
Comparison of Palatal constriction length (y-axis =# of gridlines)

Comparison of Pharyngeal constriction length (y-axis =# of gridlines)

Length of palatal constriction shortest for MM, AK second shortest.

- No difference between CH and AL.

Length of pharyngeal constriction significantly shorter for AL than CH.



Comparison of Palatal constriction location (y-axis = mm from glottis)

Comparison of Pharyngeal constriction location (y-axis = mm from glottis)

Palatal constriction location significantly more anterior for MM and AK than for AL and CH.

Pharyngeal constriction location lower in the pharynx for MM and AK.

- Significant differences observed for all speakers

CONCLUSIONS

The acoustic contribution of each gesture to F3 lowering depends on variation in the articulation of /ɹ/.

- Differences in the overall acoustic contribution of each gesture for different speakers reflect speaker-specific tendencies regarding length and location of the lingual constriction gestures.
  - Example: variation in pharyngeal aperture had less of an effect on F3 for speakers producing more inferior pharyngeal constrictions (AK and MM) than for speakers with more superior constrictions.

Findings support predictions made by vocal tract sensitivity functions regarding the effect of constriction location, length, and aperture on F3.

- Implications for the modelling of articulatory-acoustic relations in /ɹ/ and other complex segments.
- Potential implications for our understanding of how learners perceive and encode the gestural composition of /ɹ/.

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