An analysis of the articulatory features contributing to perceptual asymmetry

Ian Calloway
University of Michigan

Background

Distinct articulatory events can share a similar acoustic space

Case 1: <u>American English rhotic approximants</u>

- Similarity in acoustics of ‘bunched’ & retroflex /r/ informed by alignment in VT shape [1]

Case 2: <u>Perceptual asymmetry among v-less obstruents</u>

- Confusions between voiceless stop pairs (*described to the right*) show strong bias toward one pair member in restricted phonetic contexts
- Little evidence indicating whether vocalic context conditions [θ]-[f] asymmetry (though dissertation work suggests not)
- Like AmEng rhotics, do these productions align in VT shape in the phonetics contexts conditioning perceptual asymmetry?

Consonant Pairs Under Study

Confusable Consonant Pair	Perceptual Asymmetry Favors…	Vocalic Environment Conditioning Asymmetry
[p]-[t]	[t]	Before [i] [2,3]
[k]-[p]	[p]	Before [u] [2, but see 3]
[k]-[p]	[k]	Before [i] [2,3]
[k]-[t]	[t]	Before [i] [2,4,5]
[θ]-[f]	[f]	None specified [6,7,8]

Research Question

For consonants that show perceptual asymmetry, is acoustic similarity mirrored by similarity in the geometry of the vocal tract?

Hypothesis

Each consonant pair will show the smallest difference along acoustically-relevant articulatory measures in the vocalic context(s) that condition perceptual asymmetry.

Methodology

Data from *USC Speech and VT Morphology Database [9]*

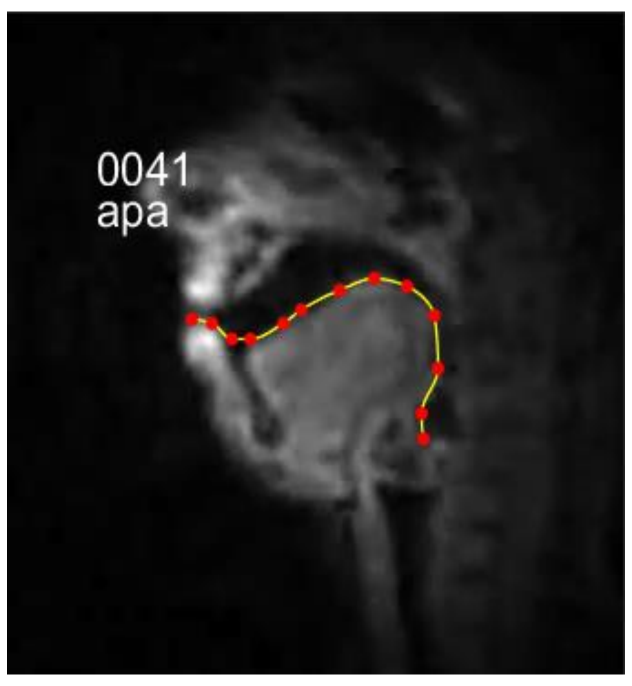
Real-time MRI video of V_1CV_1 sequences

17 speakers (9F, 8M)

<u>Vocalic Contexts</u>
[a~ɑ],[i],[u]
<u>Consonantal Targets</u>
[p],[t],[k],[f],[θ]

Two repetitions per speaker

Single frame (≤43ms) after constriction release analyzed



VT surfaces traced with GetContours package [10]

C Constriction Location (green)

V Constriction Location (green)

30-point VT area function derived from surface trace (algorithm described in [11])

<u>Articulatory Measure 1 (AM1)</u>

Absolute difference in length of VT anterior (red) to C constriction

Frication and burst acoustics sensitive to this measure [12]

<u>Articulatory Measure 2 (AM2)</u>

Euclidean Distance of VT lengths anterior (red) and posterior (blue) to V constriction

Aspiration acoustics sensitive to the lengths of these regions

Predictions

Consonant Pair	Articulatory measures predicted smallest in context of…
[p]-[t]	[i]
[k]-[p]	[i],[u]
[k]-[p]	[i]
[k]-[t]	[i]
[θ]-[f]	No difference expected

Results *(pairwise t-tests computed for vowel context pairings)*

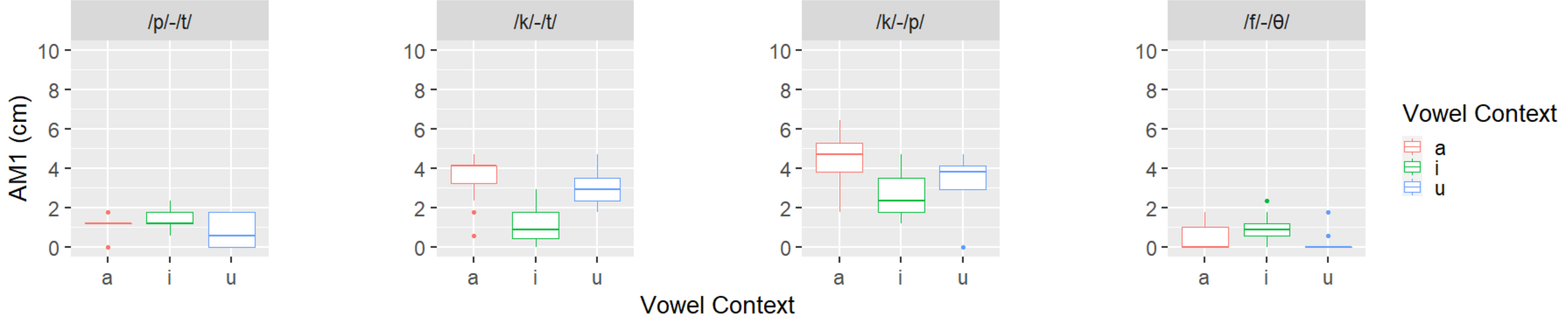
AM1
relevant to bursts/frication

X Smaller before [u] than [i] (p=0.02)

✓ Smaller before [i] than [u] (p=0.02) and [ɑ] (p=0.006)

✓ Smaller before [i] than [ɑ] (p=0.007) and before [u] than [ɑ] (p=0.02)

✓(?) No difference according to context

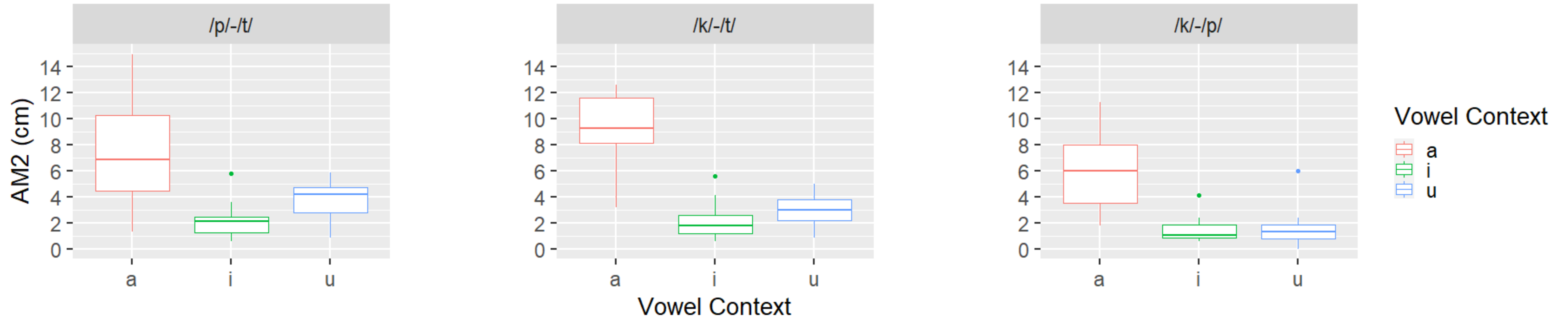


AM2
relevant to aspiration
(measure not analyzed for [f]-[θ])

✓ Smaller before [i] than [u] (p=0.02) or [ɑ] (p=0.001)

✓ Smaller before [i] than [ɑ] (p<0.0001) and [u] (p=0.02)

✓ Smaller before [i] than [ɑ] (p=0.007) and [u] than [ɑ] (p=0.02)



Discussion

AM1 Results

- Differences in AM1 partially consistent with confusion patterns in stop consonants
- AM1 appears not to vary according to vocalic context for the dental fricatives; related perceptual work also suggests confusion rates do not differ according to vocalic context
- AM1 smallest for /p/-/t/ in context of /u/; perhaps vocalic context conditions acoustic similarity independent of burst spectral characteristics (e.g., duration, amplitude);

AM2 Results

- Differences in AM2 mirror patterns of confusion among stop consonants

Conclusion

- In specific phonetic environments, voiceless obstruents can align along acoustically-relevant articulatory measures despite differences in the consonant’s constriction location
- Like Am. Eng rhotics [1,13], grossly similar VT shapes can be achieved using different combinations of articulators
- General VT shape may be relevant to consider when investigating confusions between productions with different active articulators
- Greatest similarity in VT shape for stops in the environment of [i], potentially consistent with DAC model [14]; coarticulatory resistance may also be informative to investigate why consonant confusions show context-dependence

References

[1] Zhou, X., Espy-Wilson, C. Y., Boyce, S., Tiede, M., Holland, C., & Choe, A. (2008). A magnetic resonance imaging-based articulatory and acoustic study of “retroflex” and “bunched” American English /r/. *The Journal of the Acoustical Society of America*, *123*(6), 4466-4481. [2] Winitz, H., Scheib, M. E., & Reeds, J. A. (1972). Identification of stops and vowels for the burst portion of/p, t, k/isolated from conversational speech. The Journal of the Acoustical Society of America,51(4B), 1309–1317. [3] Plauche, M. (2001).Acoustic cues in the directionality of stop consonant confusions(Unpublished doctoral dissertation). University of California, Berkeley, Berkeley, CA. [4] Guion, S. G. (1998). The role of perception in the sound change of velar palatalization.Phonetica,55(1-2), 18–52. [5] Plauche, M., Delogu, C., & Ohala, J. J. (1997). Asymmetries in consonant confusion. In G. Kokki-nakis, N. Fakotakis, & E. Dermatas (Eds.),5th European Conference on Speech Communication and Technology. [6] Miller, G. A., & Nicely, P. E. (1955). An analysis of perceptual confusions among some English consonants. The Journal of the Acoustical Society of America,27(2), 338–352. [7] Wang, M. D., & Bilger, R. C. (1973). Consonant confusions in noise: A study of perceptual features. The Journal of the Acoustical Society of America,54(5), 1248–1266. [8] Cutler, A., Weber, A., Smits, R., & Cooper, N. (2004). Patterns of English phoneme confusions by native and non-native listeners. The Journal of the Acoustical Society of America,116(6),3668–3678. [9] Sorensen, T., Skordilis, Z. I., Toutios, A., Kim, Y. C., Zhu, Y., Kim, J., ... & Nayak, K. S. (2017). Database of Volumetric and Real-Time Vocal Tract MRI for Speech Science. In *INTERSPEECH* (pp. 645-649). [10] Tiede, M., & Whalen, D. H. (2015). Getcontours: An interactive tongue surface extraction tool. *Proceedings of Ultrafest VII*. [11] Takemoto, H., Honda, K., Masaki, S., Shimada, Y., & Fujimoto, I. (2006). Measurement of temporal changes in vocal tract area function from 3D cine-MRI data. *The Journal of the Acoustical Society of America*, *119*(2), 1037-1049. [12] Stevens, K. N. (2000). *Acoustic phonetics* (Vol. 30). MIT press. [13] van Lieshout, P., Merrick, G., & Goldstein, L. (2008). An articulatory phonology perspective on rhotic articulation problems: A descriptive case study. Asia Pacific Journal of Speech, Language and Hearing,11(4), 283–303. [14] Recasens, D., Pallares, M. D., & Fontdevila, J. (1997). A model of lingual coarticulation based on ` articulatory constraints. The Journal of the Acoustical Society of America, 102(1), 544–561.