

Increased vowel contrast induced by adaptation to a non-uniform auditory perturbation in speech

Caroline A. Niziolek* and Benjamin Parrell*

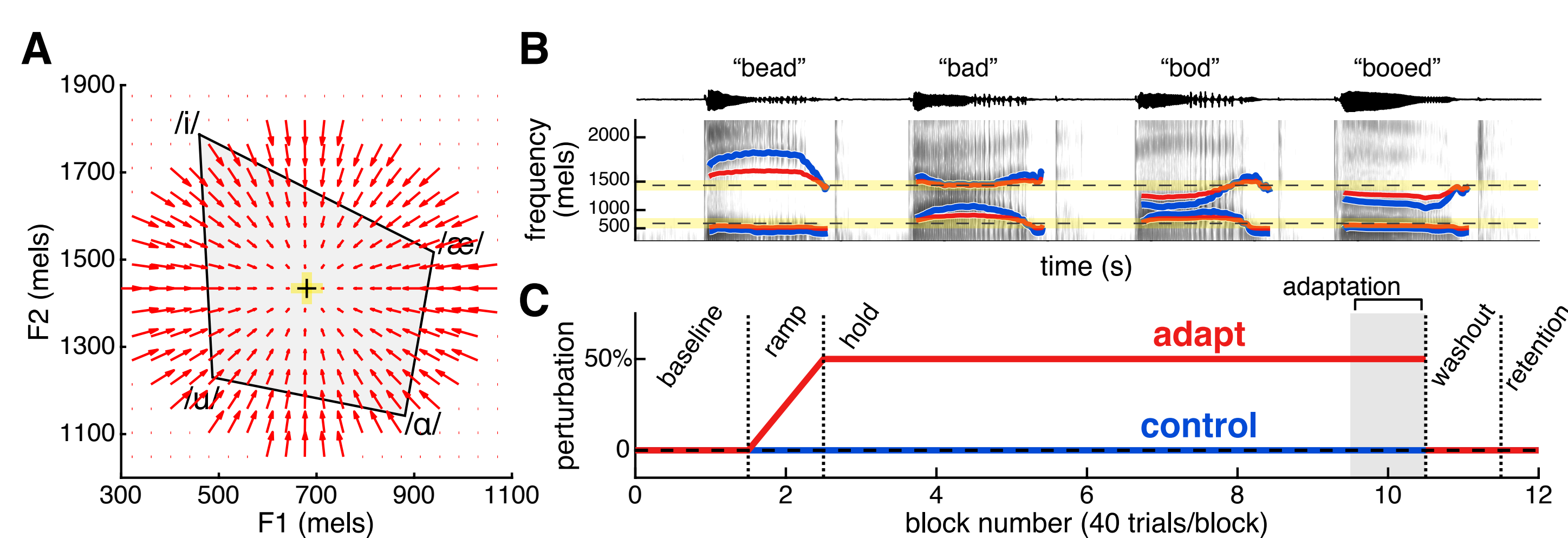
University of Wisconsin–Madison, Dept. of Communication Sciences and Disorders *equal contribution

CAN SENSORIMOTOR LEARNING DRIVE CHANGES RELEVANT FOR COMMUNICATION?

When auditory feedback is perturbed in a consistent way, speakers learn to adjust their productions to compensate, a process known as **sensorimotor adaptation**.^{1,2} While this paradigm has informed our understanding of speech sensorimotor control, its ability to induce **behaviorally-relevant changes in speech** remains unclear. Here, we examine speakers' ability to compensate for a non-uniform auditory perturbation field which was explicitly designed to affect vowel distinctiveness, by shifting all vowels towards the center of vowel space.

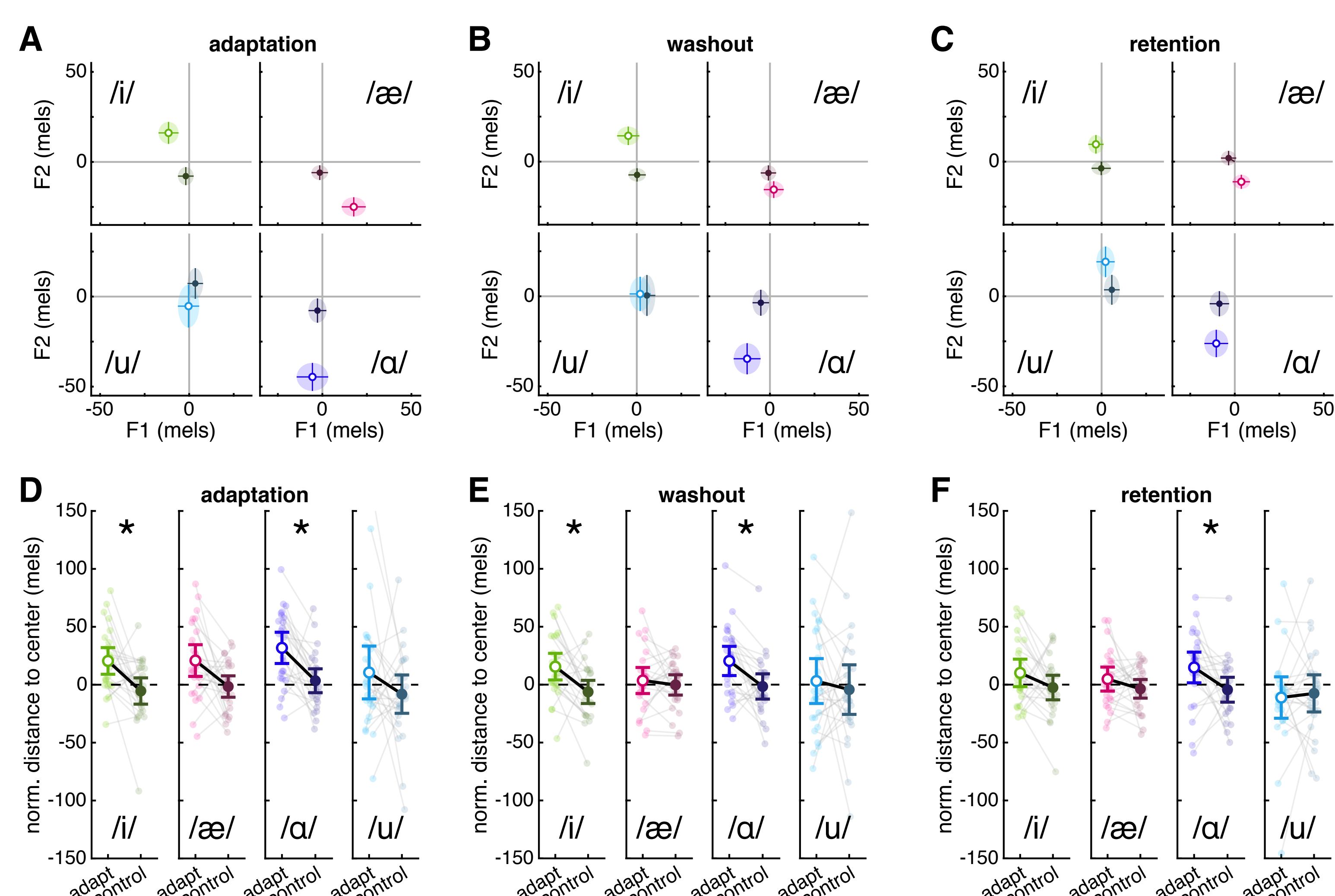
METHOD: VOWEL FEEDBACK CENTRALIZATION

English-speaking participants (n=25) read aloud words with corner vowels (*bead*, *bad*, *bod*, and *bood*) while being exposed to a “vowel centralization” perturbation. In this **adapt session**, a modified version of Audapter³ was used to shift the first two formant frequencies (F1 and F2) towards the center of each participant's vowel space, making all vowels sound more like schwa. Auditory feedback was unaltered in the baseline phase; the magnitude of the perturbation was then ramped up to reach a maximum in the hold phase, before being returned to normal in the washout phase. Ten minutes later, a retention phase again tested speech with normal feedback. Each participant also completed a **control session** with an identical procedure but with no alteration to feedback. The order of these sessions was counterbalanced.



A: Perturbation field applied to speech. B: Example spectrograms with produced (blue) and perturbed (red) formants, and the vowel space center (yellow). C: Perturbation magnitude throughout the experiment. In the **adapt session** (red), the hold phase perturbation is 50% of the 2D distance (in F1/F2 space) between the current formant values and the vowel center.

SPEAKERS ADAPTED THROUGH MULTIPLE VOWEL-SPECIFIC CHANGES

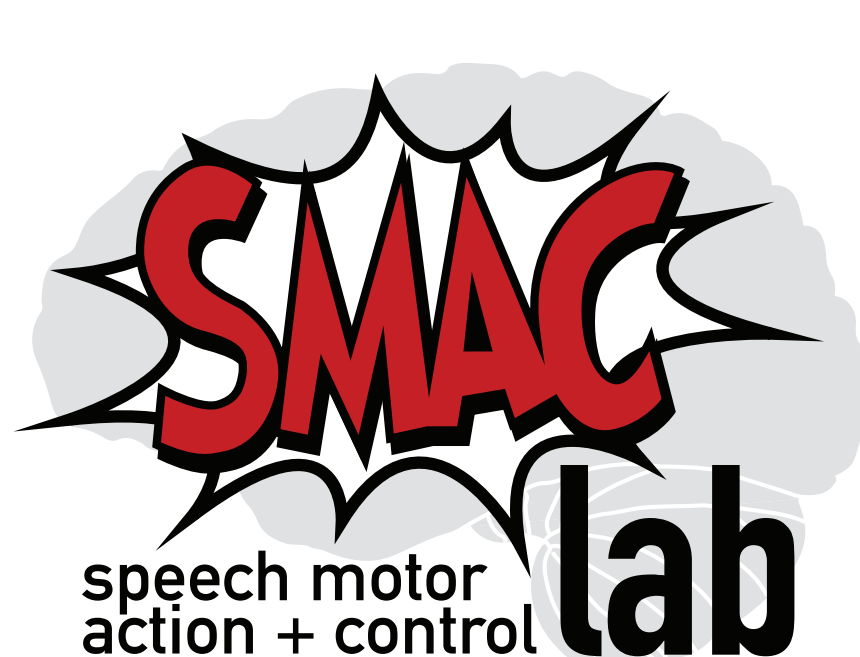


Speakers achieved these increases in speech contrast by increasing the distance between each vowel and the center of the vowel space ($p < 0.0001$) in all three test phases (A-C below). Post-hoc tests showed that /i/ was farther from the center in both the adapt and washout phases, and that /ɑ/ was farther from the center in all three test phases (all $p < 0.05$).

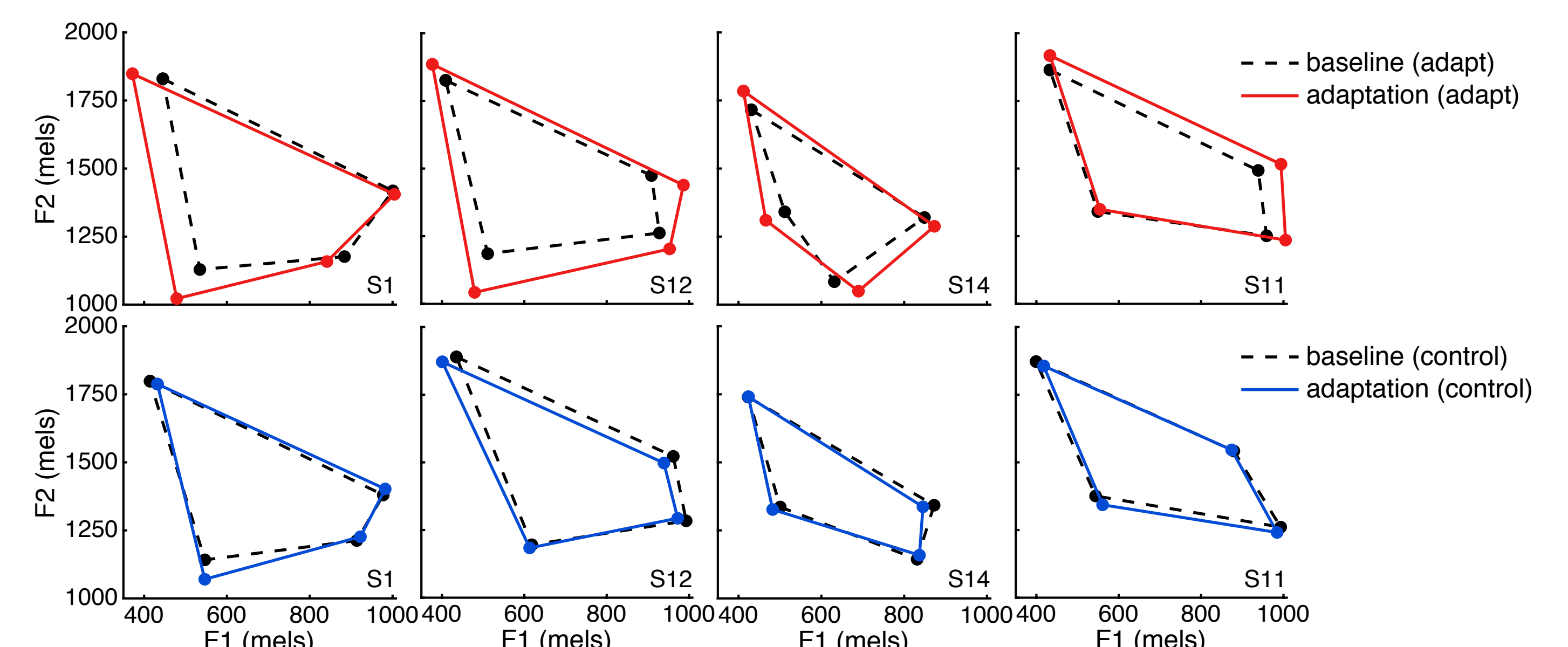
REFERENCES

- Houde, J. E., & Jordan, M. I. (1998). Sensorimotor Adaptation in Speech Production. *Science*, 294(5534), 1213–1216.
- Lametti, D. R., Rochet-Capellan, A., Neufeld, E., Shiller, D. M., & Ostry, D. J. (2014). Plasticity in the human speech motor system drives 616 changes in speech perception. *Journal of Neuroscience*, 34(31), 10339–10346.
- Cai S, Boucek M, Ghosh S, Guenther FH, Perkell J. A System for Online Dynamic Perturbation of Formant Trajectories and Results from Perturbations of the Mandarin Triphthong /iau/. In: Proceedings of the 8th International Seminar on Speech Production. Strasbourg, France: 2008, p. 65–68.

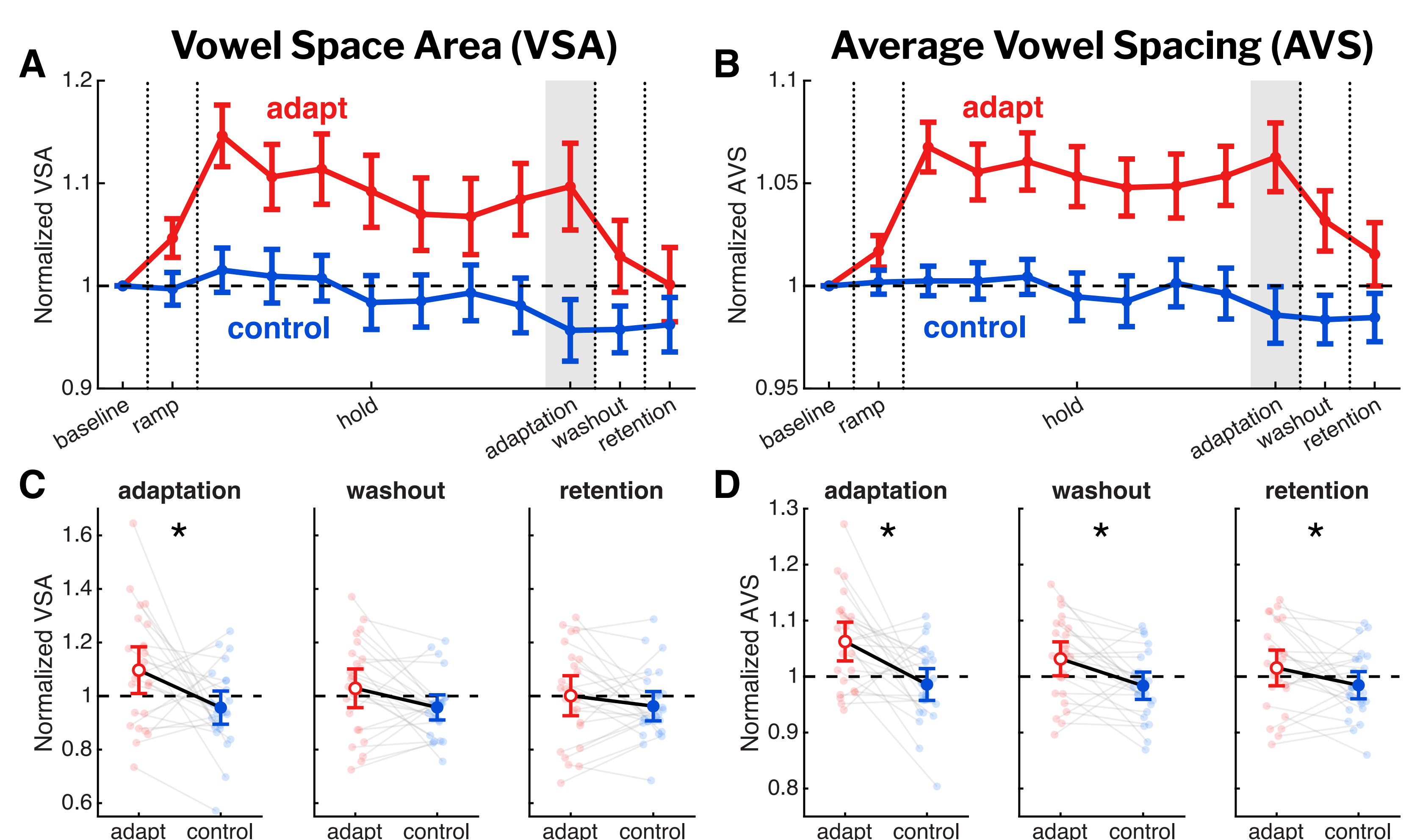
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SENSORIMOTOR ADAPTATION INCREASES VOWEL SPACE AREA AND VOWEL CONTRAST

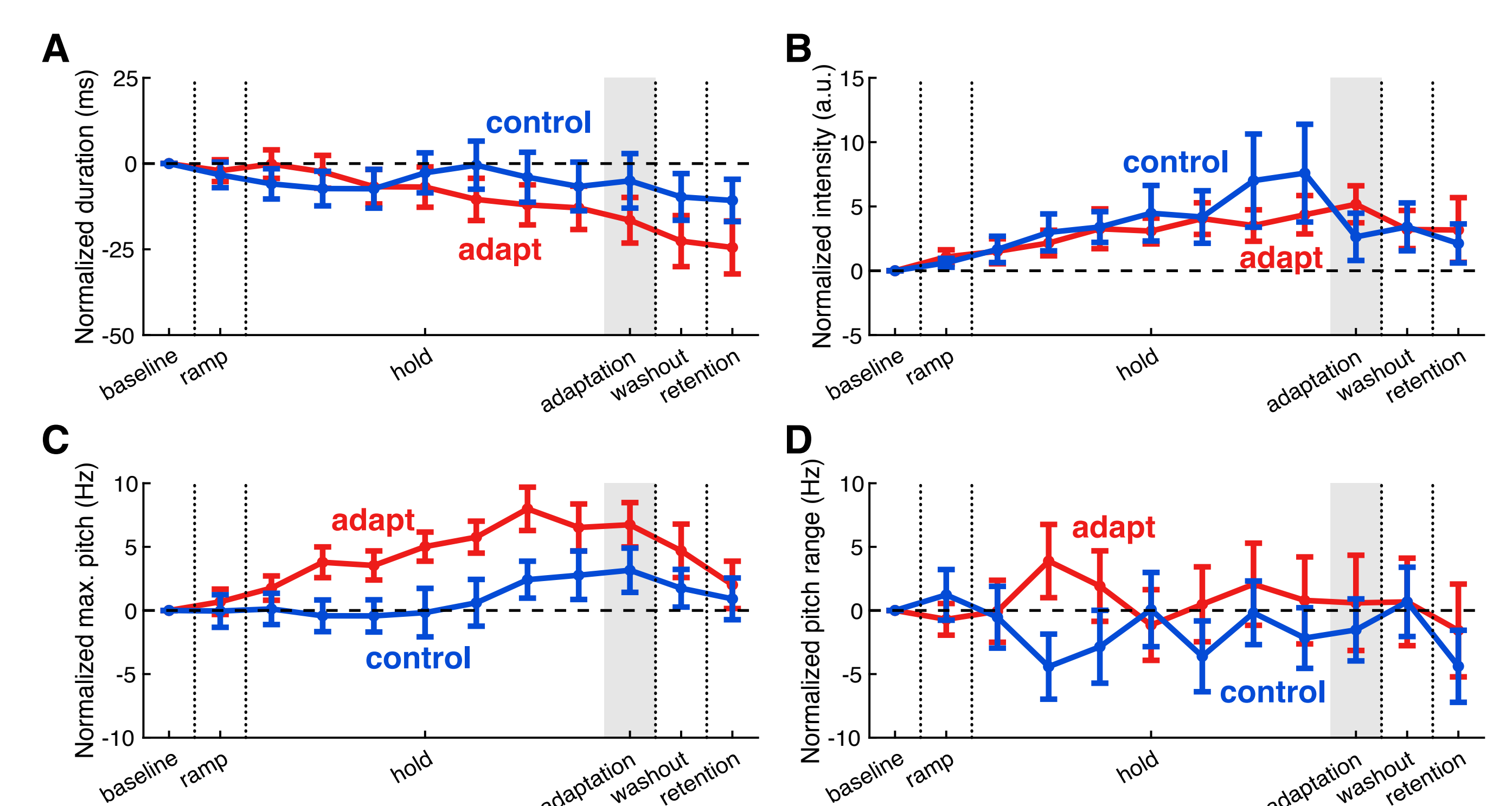


Example vowel space areas after exposure to perturbed feedback in the **adapt session** (red) or unperturbed feedback in the **control session** (blue) compared with baseline (dashed black).



Speakers responded to the perturbation by expanding VSA and increasing AVS in the **adapt session** relative to the **control session** (VSA: $p = 0.03$; AVS: $p = 0.003$). AVS changes persisted throughout the washout and retention phases (the latter following a 10-min. silent period).

INCREASES ARE NOT DUE TO “CLEAR SPEECH”



Formant changes were not accompanied by changes to other acoustic parameters associated with a clear mode of speaking. Vowel duration (A) decreased slightly over the course of the experiment, and there were only minimal changes in other speech parameters (B: peak intensity, C: maximum pitch, D: pitch range) that did not differ across sessions.

CONCLUSIONS (TL;DR)

- Altered feedback paradigms can be leveraged to increase speakers' vowel space area and the acoustic contrast between vowels—changes that have the potential to improve intelligibility.
- Increased vowel contrast persisted after a washout period and a 10-minute silent interval, evidence of potential longer-term changes.
- Speakers simultaneously learned multiple vowel-specific changes in order to compensate for the altered feedback.
- Vowel contrast increases were not the result of a “clear speech” mode, and occurred without conscious awareness or strategy, strengthening the promise of this technique for clinical use.