Formant variability is actively regulated in vowel production

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BACKGROUND

Speech movement variability is often attributed to unwanted noise in the sensorimotor system . However, recent work in reaching has demonstrated that variability may be at least in part actively controlled.

Variability is minimized along task-relevant dimensions, but permitted in less-relevant dimensions of control (Uncontrolled Manifold hypothesis [1], Optimal Feedback Control [2]).

Motor learning has been shown to selectively increase task-relevant variability, potentially to facilitate future learning [3].

Task-related variability can also be reduced when needed in some cases: participants exposed to a visual perturbation that magnified the horizontal displacement of the hand away from the midline during point-to-point reaching movements reduced their variability in this dimension [4].

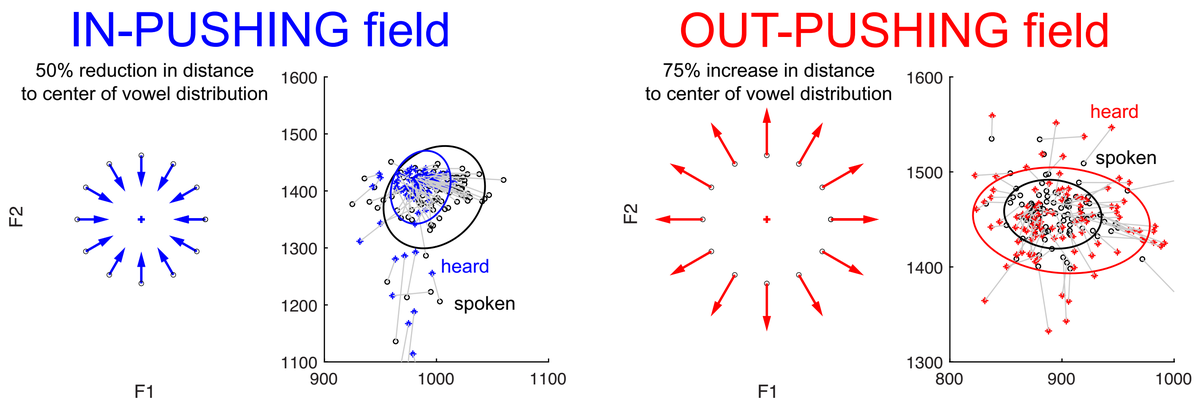
However, research on regulation of motor variability has, to date, relied principally on relatively simple, laboratory-specific reaching tasks. It is not clear if and how these results translate to speech production, a complex, well-practiced task controlled via non-visual sensory feedback.

Here, we test how variability in formant production for vowels may be actively regulated.

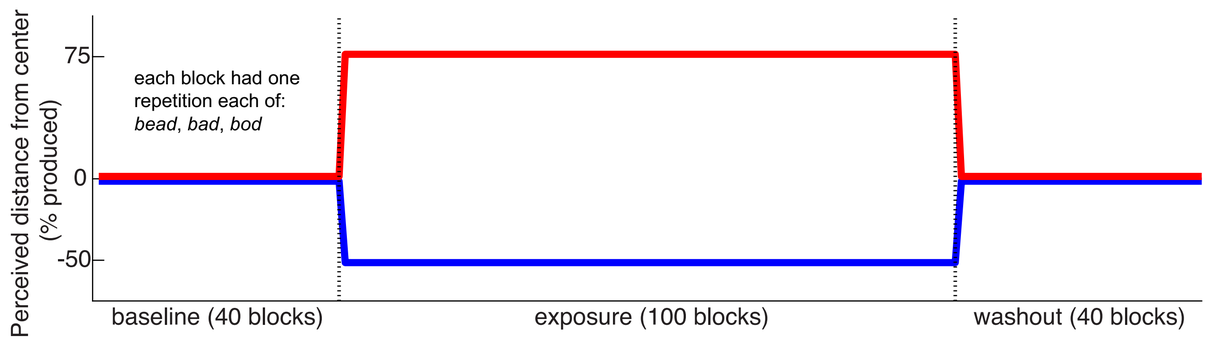
METHODS

A modified version of Audapter [5] perturbed auditory feedback during vowel production.

Participant- and vowel-specific 2D perturbation fields were created that either **decreased** or **increased** perceived variability by altering the distance of the vowel being produced to the center of that vowel's distribution in F1/F2 space.

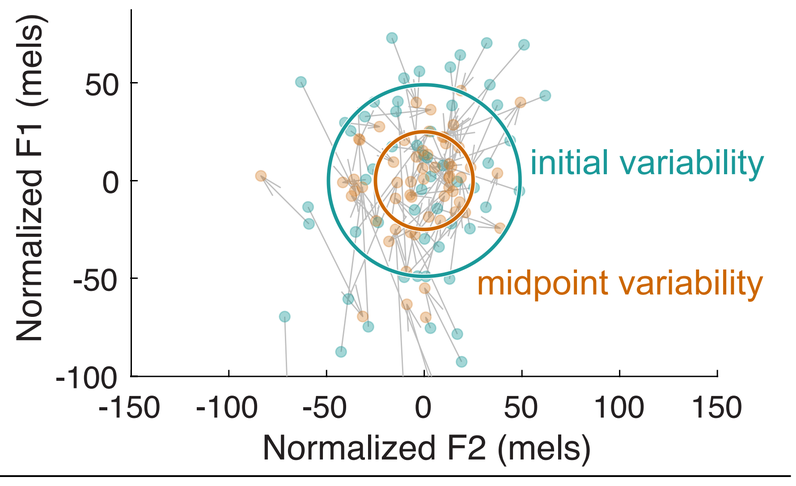


Separate groups of participants experienced **in-pushing** (n=24) and **out-pushing** (n=22) fields.



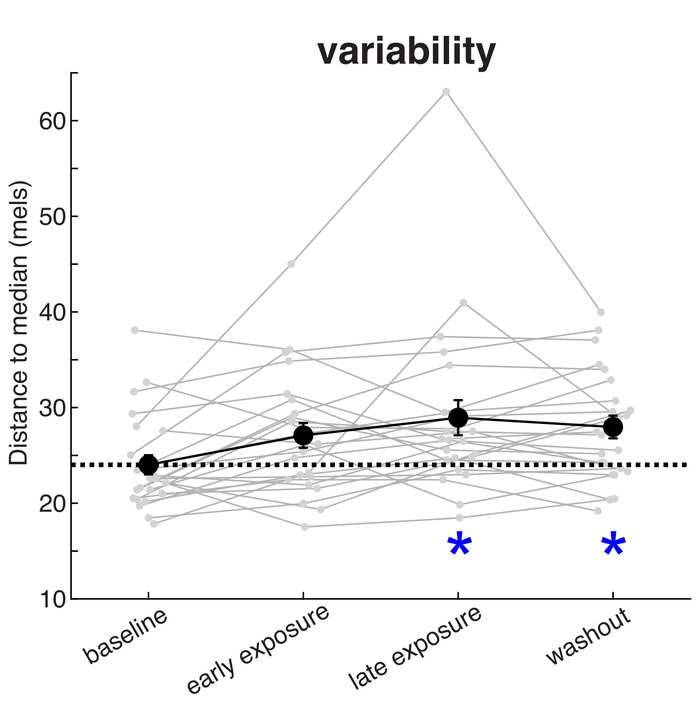
Variability: the average 2D distance in F1/F2 space between each production of a vowel and the center of the distribution for that vowel. Measured from **first 50 ms** of vowel.

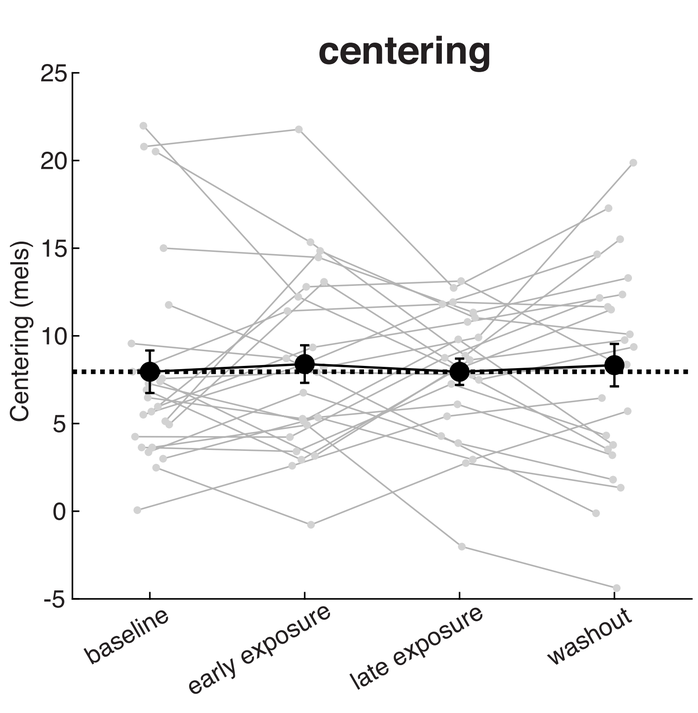
Centering: the reduction in variability from vowel onset (**first 50 ms**) to vowel midpoint (**middle 50 ms**). Centering may reflect online use of feedback to correct ongoing speech [6].



RESULTS

The **in-pushing field** increased variability (left) but had no effect on centering.





The **out-pushing field** increased centering (right) but had no effect on variability.

SUMMARY

A perturbation that reduces perceived variability "frees" the motor system to be less precise. Perhaps surprisingly, this leads to lasting changes in vowel formant variability even when normal feedback is restored, suggesting variability is monitored and regulated over relatively long time scales.

When the perturbation increased the perceived variability, no change in variability was seen. This may suggest that speech is already produced at the lower limits of possible task-relevant variability [2,3]. However, the increased centering in this condition suggests that the larger auditory errors did affect the speech control system.

Together, these results suggest that variability, even in complex tasks such as speech, is actively regulated.

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