Prediction errors drive auditory-motor adaptation in a hierarchical FACTS model

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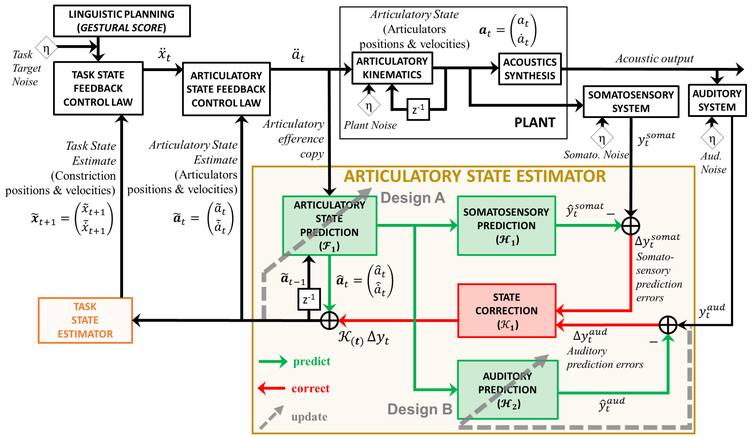
Introduction and Method

- Auditory prediction error-based mechanisms involved in speech auditory-motor adaptation were examined via the feedback aware control of tasks in speech (FACTS) model.
- Consistent with theoretical perspectives in both non-speech and speech motor control, the hierarchical architecture of FACTS relies on both the higher-level task (vocal tract constrictions) as well as lower-level articulatory state representations.

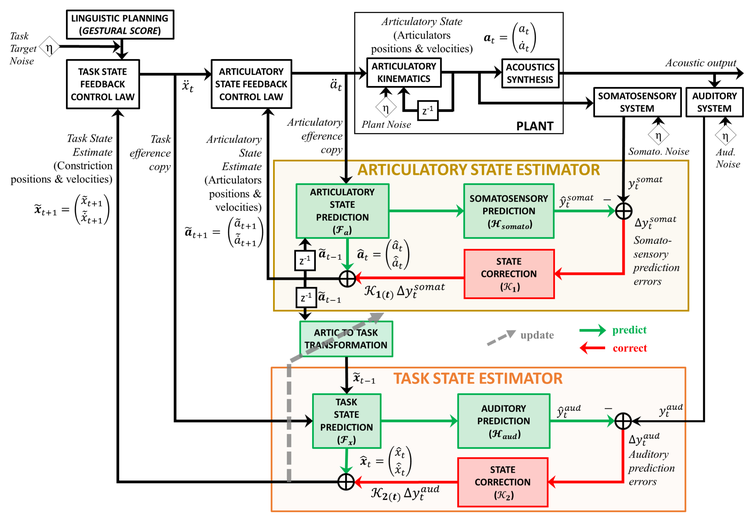


Design A

Auditory prediction errors updated the forward model that predicted the current articulatory state.

Design B

Auditory prediction errors updated the auditory forward model



Design C

Used a new hierarchical architecture with separate state feedback control loops for the articulatory level and the task level.

Auditory prediction errors updated the articulatory-to-task transformation.

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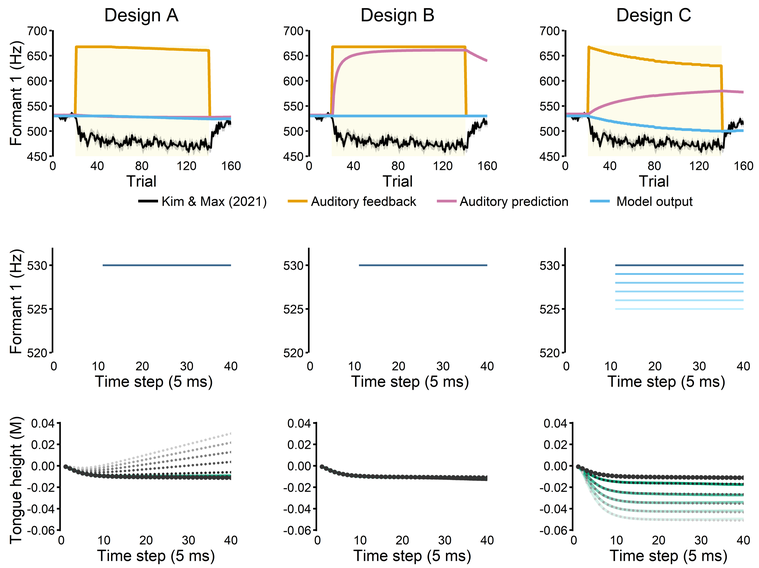
Kim, K. S., & Max, L. (2021). Speech auditory-motor adaptation to formant-shifted feedback lacks an explicit component: Reduced adaptation in adults who stutter reflects limitations in implicit sensorimotor learning. *The European Journal of Neuroscience*, *53*(9), 3093–3108.
Mitsuya, T., Macdonald, E. N., Purcell, D. W., & Munhall, K. G. (2011). A cross-language study of compensation in response to real-time formant perturbation. *The Journal of the Acoustical Society of America*, *130*(5), 2978–2986.
Mollaei, F., Shiller, D. M., & Gracco, V. L. (2013). Sensorimotor adaptation of speech in Parkinson's disease. *Movement Disorders: Official Journal of the Movement Disorder Society*, *28*(12), 1668–1674.

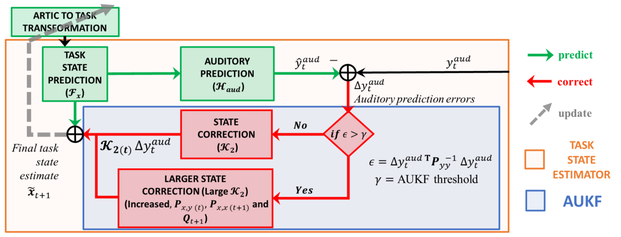
Results

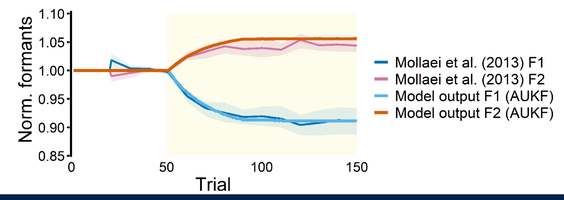


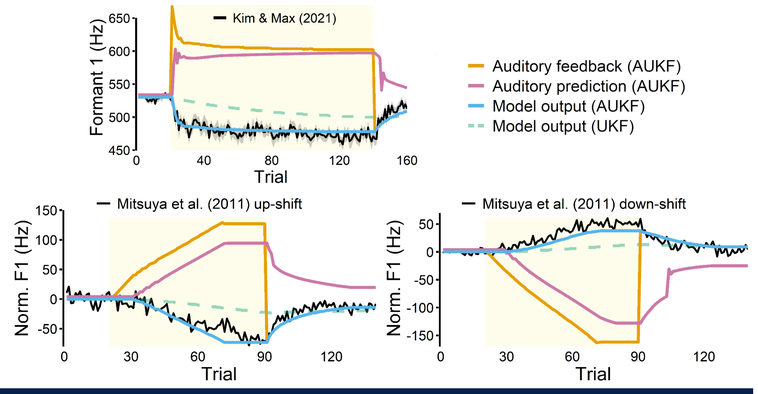
- Updating forward articulatory state (Design A) or sensory prediction models (Design B) did not cause adaptation.
- Updating the task state transformation model produced adaptation (Design C).
- The adaptive changes in Design C could also be observed in the articulatory space (e.g., tongue height).
- Nonetheless, the simulated adaptation was smaller and slower than adaptation observed in experimental data because the Kalman filter assumed a high magnitude of random noise in the sensory signals.

Design C implemented with AUKF produces realistic adaptation

In order to simulate more realistic sensorimotor adaptation, we implemented a simple adaptive unscented Kalman filter (AUKF) in Design C.







Conclusions

- **We found that adaptive behavior was present only when prediction errors updated the articulatory-to-task state transformation.**
- **In contrast, designs in which prediction errors updated forward sensory prediction models alone did not generate adaptation.**
- **FACTS demonstrated that prediction errors can drive adaptation through task-level updates.**