Brain to Voice: Understanding Speech Motor Control through Acoustic Analysis

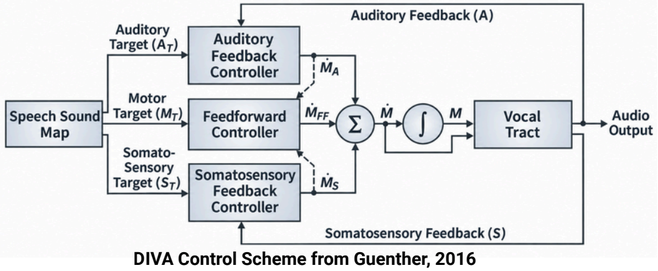
Christie Lee[2], Rosalie Gendron[1], Frank Guenther[1,3], Jason Tourville[1]

[1]Department of Speech, Language, and Hearing Sciences, [2]Department of Health Sciences, [3]Department of Biomedical Engineering

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Introduction

- Fluent, accurate speech relies on both feedforward (FF) and feedback (FB) control systems, processes captured by the DIVA model
- Speech motor programs are learned and maintained by monitoring auditory and somatosensory feedback. How do we know?
  - ***Reflexive Compensatory Response*** to *unpredictable* FB perturbations
  - ***Adaptive Compensatory Response*** following removal of *predictable* FB perturbations
- Individual variability is high in neurotypical speakers (PNT) and persons with persistent developmental stuttering (PWS; attenuated) and dyslexia (PWD, accentuated) have been associated with atypical response to these perturbations
- Overall goal: combine reflexive and adaptive FB perturbation tasks with neural modeling and neuroimaging to ***characterize individual speech profiles*** and identify their ***neural correlates*** in a hetergeneous sample
- Goal of *this* project: ***assess the reliability and specificity of individual compensatory responses,*** *and* ***provide quantitative speech motor control measures as potential biomarkers for individualized treatment in clinical settings***.
- Design: 5 FB perturbation experiments on 2 different days + MRI on the second visit; collect standardized behavioral and clinical assessments
- So far: acoustic data analyzed from 9 PNT (2M, 7F)



DIVA Control Scheme from Guenther, 2016

Future Directions

- **Modeling**: Fit SimpleDIVA model parameters to behavioral data to characterize individual speech motor control.
- **Imaging analysis:** Analyze MRI imaging data to find neural correlates.
- **Clinical cohorts:** Conduct experiments on PWS and PWD groups to compare patterns
- **Assessment analysis:** compare scored results between individuals/cohorts to find correlates.

Acknowledgements and References

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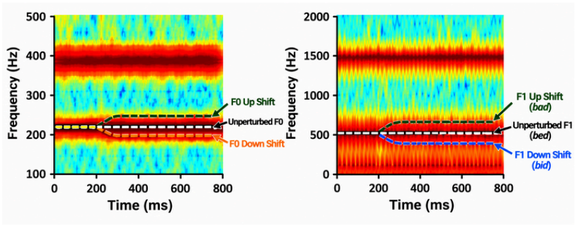
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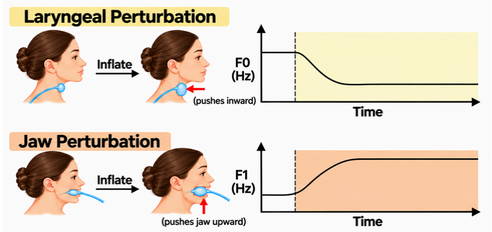
Methods

Speech Tasks

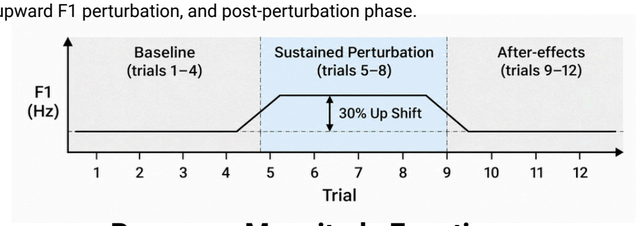
Auditory Reflexive Paradigm: Participants produced speech while hearing randomized auditory perturbation in F1 and F0.



Somatosensory Reflexive Paradigm: Participants produced speech while randomized jaw and laryngeal perturbations were applied using inflatable balloons.



Auditory Adaptive Paradigm: Participants produced speech during a baseline, 30% upward F1 perturbation, and post-perturbation phase.



Response Magnitude Equations

$$\textit{Jaw Perturbation Compensation} = \frac{\text{F1 Perturbation Peak} - \text{F1 Response Peak}}{\text{F1 Perturbation Peak}}$$

$$\textit{Laryngeal Perturbation Compensation} = \frac{\text{F0 Perturbation Peak} - \text{F0 Response Peak}}{\text{F0 Perturbation Peak}}$$

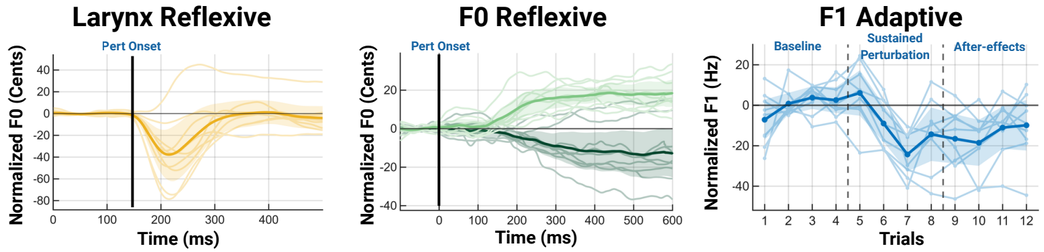
$$\textit{Reflexive F0 Compensation} = -\text{slope}(\Delta\text{F0response} \sim \Delta\text{F0perturbation})$$

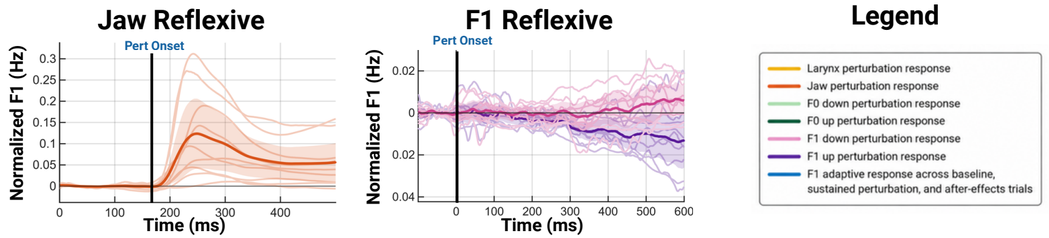
$$\textit{Reflexive F1 Compensation} = -\text{slope}(\Delta\text{F1response} \sim \Delta\text{F1perturbation})$$

$$\textit{Adaptive F1 Compensation} = \frac{(\overline{F1}_{1\text{-}4} - \overline{F1}_{9\text{-}10})/\overline{F1}_{1\text{-}4}}{0.30}$$

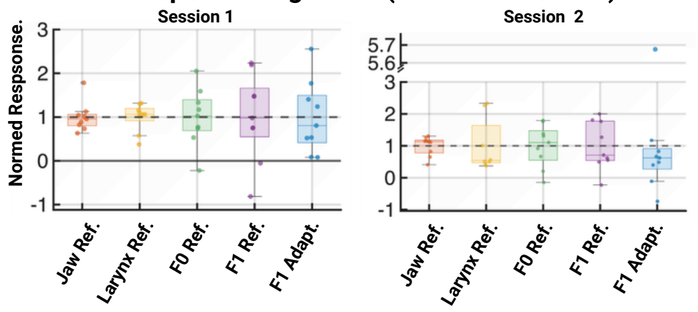
Results

Compensatory Responses (n=9)

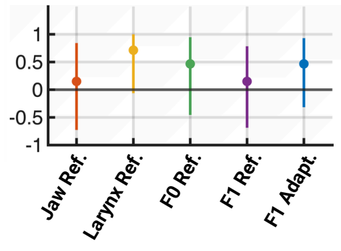




Response Magnitude (Mean Normalized)



Inter-Session Task Correlation



Summary

PNT participants (n = 9) showed significant group-level compensatory responses across all conditions except the F1 down-shift condition. Substantial individual variability was observed in the compensatory responses across tasks. Response magnitude ranks were positively correlated across sessions for all tasks, suggesting cross-session consistency in individual response patterns. However, only Session 1 correlations approached statistical significance.
Together, these findings support characterizing speech motor control at the individual level rather than relying on group averages.