# Sensorimotor Adaptation of Vowel Production in Stop Consonant Contexts

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## Background & Significance

**Sensorimotor Adaptation (SA)**

- SA is a form of short-term learning that occurs unconsciously when sensory feedback is altered[3]. In speech, adaptation is an involuntarily learned change in an articulatory movement due to perturbed auditory feedback.
- Experimental perturbations to auditory feedback produce compensatory changes in a speaker's articulation.
- Adaptation is demonstrated if speakers continue those compensatory articulations after auditory feedback has been eliminated by masking noise.
- Adaptation-based learning could be further developed to help those with motor speech disorders, requiring significantly less conscious effort than traditional speech therapy techniques.

**Coarticulation & Formants**

- Speech sounds are not produced identically in different contexts, but rather they depend upon the preceding or following speech sounds [2].
- Acoustically, vowels are characterized by their two lowest resonant frequencies (formants: F1 and F2).
- Different consonant contexts have varying effects on vowel formants due to competing demands on the articulators.

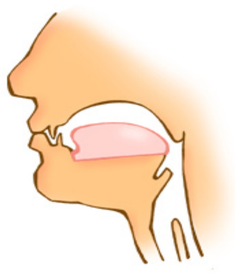


**Figure 1.** Bilabial consonant /p/

**Figure 2.** Alveolar consonant /t/

## Purpose & Hypothesis

- The purpose of this study is to measure the compensatory and adaptive articulatory responses to shifted formants in auditory feedback and to compare these effects for the vowel /e/ in two different coarticulatory contexts: voiceless consonants /p/ and /t/.
- Vowel formant frequencies were perturbed using the software *Audapt*[1], which took input speech samples and played them back to participants in real-time via headphones (Fig. 3).
- Speakers were hypothesized to shift their F1 and F2 values in the opposite direction of the perturbation.
- The magnitude of adaptation was hypothesized to be greater for the word /pep/ rather than /tet/ due to less competition for articulatory placement of the tongue in /pep/.

## Materials & Methods

- Using the *Audapt* software, the vowel /e/ in the words /pep/ and /tet/ was perturbed to sound closer to the /i/ vowel. This caused participants to perceive an error in vowel articulation (Fig. 3).
- *Audapt* shifted F1 down, and F2 up. Participants were expected to compensate for the perceived errors in their speech by shifting their F1 value up and their F2 value down (placing the tongue lower and further back).
- Participants were American English speakers with no history of speech, language, or hearing pathology. There was 1 male and 3 female subjects.

| Stage | Learning Behavior | Auditory Feedback Condition |
|---|---|---|
| Baseline | Baseline | Unperturbed |
| Ramp | Training | Gradual F1 Shift Down & F2 Shift Up |
| Full Pert | Compensation | Constant Maximum F1 Shift Down & F2 Shift Up |
| Masking | Adaptation | Noise: No Auditory Feedback |
| Return | Baseline | Unperturbed |

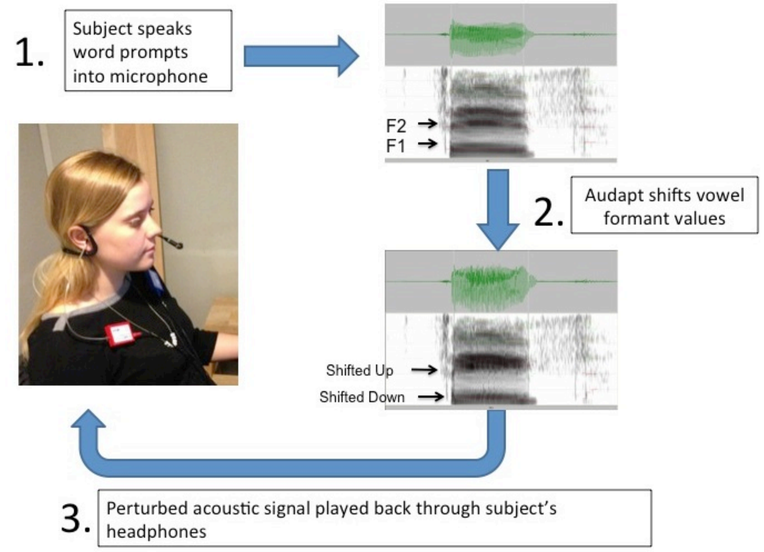



**Figure 3.** Experimental Setup

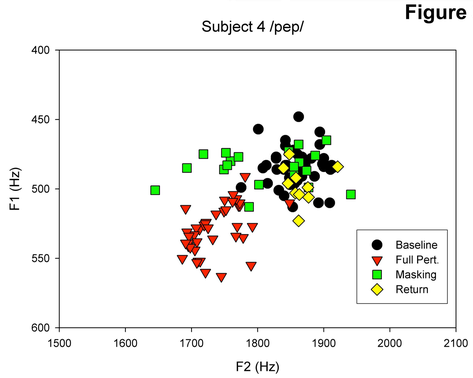



**Figure 4.** Acoustic data for /pep/, subject 4

F1 represents tongue height, and F2 represents tongue forwardness. The acoustic differences between experimental phases suggest that subject 4 made large changes in articulation, consistent with SA of the vowel in /pep/.

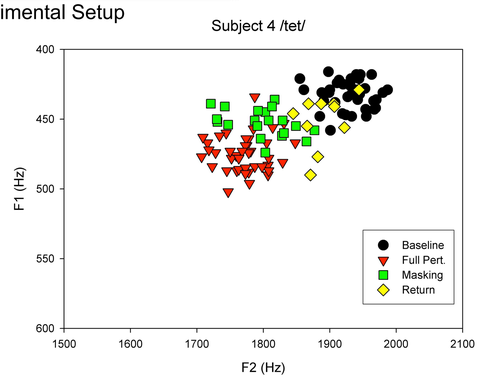



**Figure 5.** Acoustic data for /tet/, subject 4

Subject 4 also displayed SA for /tet/ based on F1 and F2 changes between phases, but with smaller overall magnitude compared to /pep/ indicated by the more condensed data points.

## Results

**Figure 6.** /pep/ Subject Averages

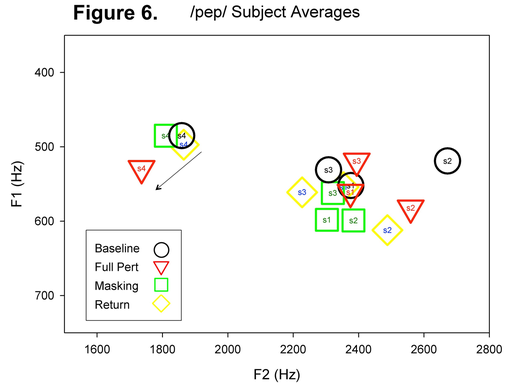
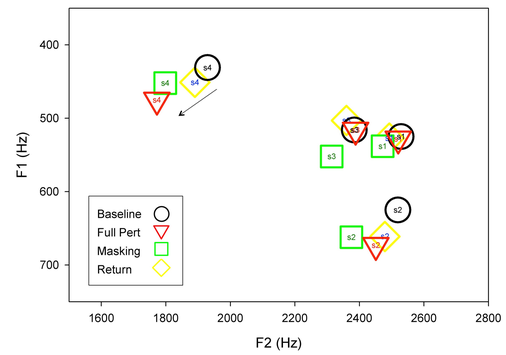



**Figure 7.** /tet/ Subject Averages




## Conclusions

- For the word /pep/, there appears to be a greater degree of compensation and adaptation that occurred across subjects. 3/4 subjects displayed shifts in their formant values that were consistent with the hypothesis.
- The magnitude of the shift was more significant in /pep/, as indicated by the greater spread of data points across phases.
- Speaker-specific differences were noted, for example, subject 4 displayed more change in F2 than F1, suggesting greater backward change in tongue position than downward change.
- Overall, /pep/ is a more facilitatory consonant context for vowel SA, resulting in greater involuntary tongue position change.

## References

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## Acknowledgements

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