Sensorimotor Adaptation of Speech Through a Virtually Shortened Vocal Tract

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The purpose of this research is to understand how auditory feedback manipulations may be used to elicit involuntary changes in speech articulation.

Sensorimotor adaptation (SA) is a learning phenomenon that has potential for speech rehabilitation (Houde & Jordan, 1998).
Participants speak through a digital audio processing device that virtually manipulates the perceived size of their vocal tract, thus affecting the acoustic vowel space.

This altered perception of vowel space causes changes in speech movements.

A smaller vocal tract correlates with a larger acoustic space, and vice versa (Turner & Tjaden, 1995).
When this line of research is further developed, the clinical focus is to determine if speech SA can be used as therapy for those with motor speech disorders (for whom there is currently no effective treatment).

- Paralysis or incoordination in the muscular control necessary to produce intelligible speech (e.g. reduced vowel space due to constricted articulatory space) (Kent, 2002; Turner & Tjaden, 1995).
Research Questions

- How will modifying the perception of vocal tract size affect articulatory behavior, indicated by changes in formant frequencies and vowel space area?
- How will the size of the virtual vocal tract affect the magnitude and direction of sensorimotor adaptation for speech?
How important is it for the virtual space to mimic the talker’s real space?

Will perturbing the size of the perceived vowel space facilitate or impede involuntary adaptive learning for speech?
Hypothesis

By having participants speak through a virtual vocal tract that is perceived to be of a shorter length than their actual vocal tract, talkers will create compensatory and adaptive speech behaviors indicated by changes in their formant frequency values as well as changes in their vowel space area.
Methodology

Participants speak through the TC Helicon, a digital audio processing device. Participants were recorded saying repetitions of single words as well as passages.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Learning Behavior</th>
<th>Auditory Feedback Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>Baseline</td>
<td>Unperturbed</td>
</tr>
<tr>
<td>Feedback</td>
<td>Compensation</td>
<td>Perturbed auditory feedback</td>
</tr>
<tr>
<td>Masking</td>
<td>Adaptation</td>
<td>Noise: No auditory feedback</td>
</tr>
<tr>
<td>Baseline</td>
<td>De-adaptation</td>
<td>Unperturbed</td>
</tr>
</tbody>
</table>
By measuring formant frequency values (F1 & F2) across different parameters on the TC Helicon, this can indicate changes in articulation.

Acoustics were measured by taking F1 and F2 values for each vowel repetition at the midpoint of the vowel.

These values were averaged across parameters to calculate a vowel space area for each novel virtual vocal tract.

Formant values were obtained using TF32 software, and formant averages were calculated using R, a statistical computing software.
Acoustic Results

- Subjects show changes in articulation based on variations in vowel space areas across different parameters on the TC Helicon.
- Subjects also indicate changes in formant frequency values across parameters.
Vowel Area Results

- Vowel space area is a measure of the overall acoustic working space.
- NH tends to start small and get bigger as the perceived vocal tract size shortens (a “following” response).
- ER tends to start big and gets smaller (a “compensatory” response).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>NH</th>
<th>ER</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>375439</td>
<td>492162</td>
</tr>
<tr>
<td>10</td>
<td>355476</td>
<td>412240</td>
</tr>
<tr>
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<td>437806</td>
<td>380320</td>
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<td>396770</td>
<td>289943</td>
</tr>
<tr>
<td>50</td>
<td>391619</td>
<td>257917</td>
</tr>
</tbody>
</table>
Participant NH demonstrates vowel specific changes (primarily /i/ and /u/) in formant frequencies that correspond with a general tendency toward movement of the tongue up and backward as the perceived vocal tract shortens.

This trend is not strict since extreme values appear to move back towards baseline, suggesting that when the perceived vocal tract is extremely different from the talker’s, adaptive changes may be reduced.
Participant ER exhibits vowel specific changes (mostly for /u/) that correspond with movement of the tongue down and forward as the perceived vocal tract shortens.

This trend is quite strict, although the effect is almost exclusively for /u/.
Across participants NH and ER, the results were idiosyncratic in the articulatory response in both the direction and magnitude of the adaptation effects.

The greatest changes occurred for the vowels /i/ and /u/.

If further developed, speech sensorimotor adaptation has potential for rehabilitation applications, ideally for those with motor speech disorders.
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References

- https://notendur.hi.is/peturk/KENNSLA/02/TOP/VowelSpace.html