Effects of Following Voicing on Perceived Vowel Duration

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Background

- Vowels are longer before voiced consonants than voiceless consonants in English and many other languages, though some languages lack the effect (Chen 1970; Keating 1979)
- Various explanations have been proposed, driven either by articulatory or perceptual factors (e.g. Chen 1970, Kluender et al. 1988), but the underlying cause remains in question
- The difference in vowel duration is used as a perceptual cue for codas voicing in English (e.g. Port & Dalby 1982)

This study:

- Two experiments on how coda voicing affects perception of preceding vowel duration
- The presence of voiceless codas creates a bias towards categorizing vowels as long
- The acoustic effects of voiceless codas, when the codas themselves have been removed, create a bias towards categorizing vowels as short

Methodology

- Study 1: Categorization of vowels in VC nonce words as ‘long’ or ‘short’ (24 listeners, native English speakers)
  - Voiced and voiceless stop codas
  - Blocks based on vowel quality (/a/, /i/, /u/)
  - 10-step vowel duration continuum (129 ms to 252 ms)
- Study 2: Categorization of isolated vowels as ‘long’ or ‘short’ (24 listeners, native English speakers)
  - Extracted from the same VC nonce words, with the codas and transitions into them removed
  - Blocks based on vowel quality (/a/, /i/, /u/)
  - 10-step vowel duration continuum (129 ms to 252 ms)

Summary of results: Regression models

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Std. Error</th>
<th>t value</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>-2.35</td>
<td>0.22</td>
<td>-10.7</td>
</tr>
<tr>
<td>DurationStep</td>
<td>0.31</td>
<td>0.016</td>
<td>18.9</td>
</tr>
<tr>
<td>CodaVoicing-Voiceless</td>
<td>0.41</td>
<td>0.086</td>
<td>4.83</td>
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<tr>
<td>Vowel-i</td>
<td>0.58</td>
<td>0.11</td>
<td>5.54</td>
</tr>
<tr>
<td>Vowel-u</td>
<td>0.72</td>
<td>0.11</td>
<td>6.785</td>
</tr>
<tr>
<td>ResponseTime</td>
<td>-0.023</td>
<td>0.070</td>
<td>-0.33</td>
</tr>
</tbody>
</table>

Table 1: Generalized linear mixed effects model for ‘long’ responses in Study 1

<table>
<thead>
<tr>
<th>Intercept</th>
<th>DurationStep</th>
<th>OrigCodaVoiceless</th>
<th>Vowel-i</th>
<th>Vowel-u</th>
<th>ResponseTime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimate</td>
<td>Std. Error</td>
<td>t value</td>
<td>p value</td>
<td>&lt; 0.0001***</td>
<td>&lt; 0.0001***</td>
</tr>
<tr>
<td>0.40</td>
<td>0.015</td>
<td>30.6</td>
<td>0.66</td>
<td>0.024*</td>
<td>0.74</td>
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</tbody>
</table>

Table 2: Generalized linear mixed effects model for ‘long’ responses in Study 2

Study 1: Vowels with codas present

Coda voicing was a significant factor; listeners gave more responses of ‘long’ when the coda was voiceless than when it was voiceless

This effect follows from knowledge of English phonology; shorter durations are expected in this environment, so listeners compensate in their threshold for ‘long’ vowels

A similar compensatory pattern for vowel qualities of different intrinsic duration (see Table 1)

Figure 1: ‘long’ responses, by coda voicing

Study 2: Vowels with codas spliced out

More responses of ‘long’ for vowels produced before a voiced coda, when that coda was removed

Suggests an effect of acoustic differences within the vowels; note that this is the opposite of the effect when codas were present

Several acoustic characteristics of vowels are influenced by following consonants; vowels before voiced stops have a lower F0, lower F1, higher harmonics-to-noise ratio, and less jitter

Figure 2: ‘long’ responses, by original coda voicing

Conclusions

Effects of phonologically expected duration

- Vowels are longer before voiced consonants, so their duration is used as a cue for coda voicing
- Similarly, codas set expectations about vowel duration, with longer durations anticipated before voiced codas
- Suggests that cue interaction is bidirectional, with usage depending on the task

Effects of acoustic characteristics

- Without phonological biases driven by the presence of codas, acoustic differences due to production of coda voicing make vowels from voiced environments sound longer
- Suggests a possible perceptual pathway for a voicing-conditioned vowel duration difference

Table 3

<table>
<thead>
<tr>
<th>Estimate</th>
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<th>t value</th>
<th>p value</th>
</tr>
</thead>
<tbody>
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<td>Vowel-i</td>
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<td>Vowel-u</td>
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<td>ResponseTime</td>
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<td>0.069</td>
<td>-0.32</td>
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Selected References