Investigating lexically conditioned phonetic variation using ultrasound

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Introduction

- Ultrasound has been used to investigate a wide range of issues (from tongue movements in disordered speech to tongue shapes during clarinet performance)

- Majority of linguistic ultrasound studies investigate variation in tongue shapes due to **phonological motivations** (coarticulation, phonotactics, and prosody)
Introduction

- Other sources of variation in phonetic realization: **Lexically conditioned variation**

- Word frequency effects and neighborhood density effects have been shown to induce phonetic variation:
  - High frequency words $\rightarrow$ phonetically reduced (Jurafsky et al., 2002; Bell et al., 2007, Aylett & Turk, 2006 among others)
  
  - Low neighborhood density words $\rightarrow$ phonetically reduced (Scarborough, 2004; Munson & Solomon, 2004)
Introduction

• Data collection with ultrasound often requires collection of several repetitions of the linguistic target gesture

• However, repetition also induces reduction (Fowler & Housum, 1987; Gregory et al., 1999; Aylett & Turk, 2004)

• Possibility: reduction due to repetition may obscure reduction due to lexical effects
Introduction

• Goal of this study:
  
  – Investigate reduction in magnitude of tongue gestures due to repetition
  
  – Test feasibility of ultrasound use for investigating effects of neighborhood density on the magnitude of tongue gestures
• **Neighborhood density** (Luce & Pisoni, 1998)
  
  • Number of words created by the addition, substitution or deletion of a single segment

<table>
<thead>
<tr>
<th>Low Neighborhood</th>
<th>High Neighborhood</th>
</tr>
</thead>
<tbody>
<tr>
<td>dog</td>
<td>sing</td>
</tr>
<tr>
<td>hog, fog, frog, log, bog, dig, dock, ... (n=8)</td>
<td>sang, sung, ring, thing, sting, sling, sick, sill, sit, sick, sip, ... (n=22)</td>
</tr>
</tbody>
</table>
Introduction

• Issues in investigating neighborhood density and frequency:
  • Challenging to create stimuli for both
  • BUT stimuli testing neighborhood density effects are somewhat easier to construct (frequency effects can only be investigated with homophones)
Method

• Stimulus material:
  – Word pairs that minimally differ in the initial consonant of a CIVk word
  – One word of the diad is a high neighborhood density word the other is a low density neighborhood word

• Words were controlled for frequency
## Method

<table>
<thead>
<tr>
<th>High Density Neighborhood</th>
<th>Low Density Neighborhood</th>
</tr>
</thead>
<tbody>
<tr>
<td>word</td>
<td>word</td>
</tr>
<tr>
<td>DenB</td>
<td>DenB</td>
</tr>
<tr>
<td>clack</td>
<td>flak</td>
</tr>
<tr>
<td>23</td>
<td>17</td>
</tr>
<tr>
<td>slack</td>
<td>plaque</td>
</tr>
<tr>
<td>19</td>
<td>12</td>
</tr>
<tr>
<td>slag</td>
<td>flag</td>
</tr>
<tr>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td>cloak</td>
<td>bloke</td>
</tr>
<tr>
<td>13</td>
<td>10</td>
</tr>
</tbody>
</table>

- **Subjects:** four native speakers of American English (2 female & 2 male)
Method

• Procedure:
  – Word list with target words (including three distracter words at beginning of list) was read by subjects (Fowler, 1988 found no repetition effect for word lists)
  – Each speaker produced 9 repetitions of target words while tongue movements were scanned (Antares Sonoline) at 29.95 fps
Method

- Procedure:
  - Participants’ heads were stabilized during data collection (cf. Davidson & Decker, 2005)
Analysis

- recordings of target vowels were extracted as sequence of JPEG images:

- frame of most advanced position of tongue body for the vowel [æe] was selected (cf. Benus & Gafos, 2007)
Analysis

- Curvature of tongue in target frame was traced using EdgeTrak (Li et al., 2005)
Analysis

- Tracings of the repetitions were averaged and compared using assist package (Wang & Ke) in R
Analysis

– Data were analyzed for each participant by comparing:
  • The tongue shape of the vowel averaged over the first three repetitions to the last three repetitions
  • High density neighborhood word (clack) to low density neighborhood words (flak and plaque)
  • The same comparisons were made averaging only over the first three repetitions, the 4th through 6th repetition, and the 7th through 9th repetition.
Results

• Out of the 11 words analyzed (across all 4 talkers), in 10 words the first three repetitions differed significantly from the last three repetitions:
Results

- Comparing the vowel in the high density neighborhood word (clack(23)) to the vowel in the two low density neighborhood words (flak (17) and plaque (12)):

  clack vs. flak: 1/4
  clack vs. plaque: 2/3

- Overall 3/7 show the expected pattern when averaging across all 9 repetitions.
Results

• Comparing the vowel gesture in high and low density neighborhood words averaged across the first three repetitions: 6/7 show expected patterns

• The tongue is more advanced in the high density neighborhood word, when averaged over the first three repetitions
Summary

- The neighborhood effect is less visible in later repetitions:
Conclusion

• Results suggest:

  – Despite using a wordlist, we see reduction of the vowel gesture in later repetitions

  – Lexically conditioned phonetic variation can be investigated with ultrasound as long as number of repetitions are kept small
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