Perceptual similarity and phonetic context in native English listeners’ perception of Arabic consonants

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PURPOSE
The Arabic language has consonants that do not exist in English. Some of these consonants have contrasting features that also do not exist in the English language. While these sounds are known to be challenging for students of Arabic, quantitative data on which pairs of sounds are most confusable are not generally available. The University of Maryland Center for Advanced Study of Language (CASL) and the University of Cincinnati developed a corpus of perceptual errors for English learners of Arabic. This corpus was built to evaluate and improve CASL-built software for assisting native English speakers learning Arabic (Rytting et al., 2010). Here we show how we administered a spelling test to build this perceptual error corpus and highlight a few of the initial findings.

GUIDING HYPOTHESES
For Arabic learners, phones (and distinctions) not found in the English language will be more difficult to distinguish than those shared with English. Furthermore, phonological features not used in English will be particularly difficult (e.g., Best et al., 2001; Flege, 1993). Our evaluation focused on the emphasis (pharyngealization) feature and place distinctions not found in English (e.g., velar vs. uvular, pharyngeal vs. glottal). Also, because the phonetic cues associated with pharyngealization can spread to neighboring segments (cf. e.g., Bin-Muqbil, 2006; Jongman et al., 2007), the presence of another emphatic consonant nearby will make the “emphasis” distinction even more difficult to distinguish.

RESULTS

1. Overall consonant distances across contexts

The dendrogram below shows how consonants cluster naturally from the substitution error data collected across all 15 contexts. Horizontal lines connecting two consonants or clusters are placed to show the calculated distance between those two entities.

<table>
<thead>
<tr>
<th>#</th>
<th>C</th>
<th>V</th>
<th>V</th>
<th>V</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>#_V</td>
<td>C_V</td>
<td>C V</td>
<td>V V</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>EmphAfter</td>
<td>NoEmph</td>
<td>EmphBefore</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

METODOLOGY AND ANALYSIS
We tested 70 subjects from five universities in the United States. All subjects were native English speakers either currently or recently enrolled in Arabic language courses for at least two semesters. Excluded from the study were Arabic-heritage speakers and non-English dominant bilinguals. The test consisted of 261 words recorded in a neutral Arabic accent, that is, without a regional accent. The subjects were asked to write down the word they heard, including short vowels and geminate marker. Results were coded based on the following:

- Blanks and other problematic responses were excluded from analysis.
- Responses were automatically phone-aligned with stimuli.
- Root consonants (except glides) were analyzed for errors (substitutions and omissions).
- From the resulting confusion matrices, similarity, bias, and distance scores were calculated:

\[
s(k, q) = \frac{b(q)}{b(q) + b(k)}
\]

\[
b(q) = \sum \frac{p(q)}{p(q) + p(q)}
\]

\[
d(k, q) = -\ln s(k, q)
\]

2. The role of phonetic context

Consonants were most easily distinguished between a vowel and a word boundary; word-medial positions (including intervocalic) were slightly harder. The most challenging position was between a consonant and the end of the word.

<table>
<thead>
<tr>
<th>By phonetic context</th>
<th>Context</th>
<th>% Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>#_V</td>
<td></td>
<td>77.1</td>
</tr>
<tr>
<td>V_#</td>
<td></td>
<td>77.0</td>
</tr>
<tr>
<td>C_V</td>
<td></td>
<td>74.9</td>
</tr>
<tr>
<td>V_C</td>
<td></td>
<td>74.7</td>
</tr>
<tr>
<td>V_V</td>
<td></td>
<td>74.1</td>
</tr>
<tr>
<td>C_#</td>
<td></td>
<td>63.9</td>
</tr>
</tbody>
</table>

3. The role of neighboring emphatic consonants

These six figures illustrate the role of neighboring emphatic consonants on some of the most difficult distinctions for English learners of Arabic. Contexts for the target consonant are as follows:

- A = “EmphAfter” or _ (V)CE
- N = “NoEmph” other than (possibly) the target consonant itself
- B = “EmphBefore” or C(V)

Emphasis in coronals is generally harder to distinguish nearby another emphatic consonant.

CONCLUSIONS
Many, but not all, contrasts were difficult to perceive accurately:

- Emphatic-plain pairs
- Velar-uvular stops
- Pharyngeal fricatives with acoustically closest counterparts

METHODOLOGY AND ANALYSIS

REFERENCES


