Approaches to

References

Introduction

Historical changes of \([\text{kw}] \rightarrow \text{[p]}\) or \([\text{b}]\) are attested in many languages...

But in ancient Greek: \(\text{kw} \rightarrow \text{p}\) before \(o, a, C\)
\(\text{kw} \rightarrow \text{t}\) before \(e, i\)

The possibility that these sound changes were prompted by perceptual confusion has been discussed \([3, 6]\), but no research has sought to identify universal perceptual biases that might explain these recurring sound changes.

Acoustics of the Stimuli

F\(_1\) and F\(_2\) frequencies were measured from the onset of voicing immediately following the burst portion of the obstruent, and from mid-vocalic position, for stops \([p, t, k, \text{kw}]\) preceding English vowels \([i]\) and \([o, a]\) in monosyllabic English words. Words were grouped according to initial stop and vowel.

1. English kwo and po words are acoustically dissimilar to one another during the transition stage.

2. At vocalic onset before close vowels, labiovelars and labials are acoustically dissimilar, and remain divergent throughout the vocalic portion.

The acoustic evidence suggests that perceptual confusion between \([\text{kw}]\) and \([\text{p}]\) is unexpected in either vocalic context.

Methodology and Results

Participants heard single word stimuli masked by pre-recorded conversational babble, selected at random for each individual stimulus word to control for variable intensity in the speech noise. The signal-to-noise ratio was 2:3, or ~1.76 dB.

The background noise reflected the frequency distribution of normal human speech and was sufficient to mask formants 1 to 3 of all stimulus tokens used in the experiment (see Figure 2).

Stimuli from three female and three male speakers were used to control for individual differences between speakers, and eliminate the risk of selecting material from an anomalous speaker by chance. Subjects were asked to select from three options which word they believe they heard.

![Figure 1: Euclidean distances at the onset of voicing for words in po, to, ka and kwo categories.](image)

![Figure 2: LATs of stimuli and masking noise.](image)

Proportions of responses to [kw] stimuli before a back rounded vowel

No participants confused [kw] for [p] at a high rate before back rounded vowels, or in any other vocalic environment

Table 1: Historical developments of labiovelars to labials.

<table>
<thead>
<tr>
<th>Family</th>
<th>Language</th>
<th>Change</th>
<th>Environment</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indo-European</td>
<td>Ancient Greek</td>
<td>(k^* \rightarrow p)</td>
<td>(\text{[o, a, C]})</td>
<td>[2]</td>
</tr>
<tr>
<td></td>
<td>(k^* \rightarrow t)</td>
<td>(\text{[e, i]})</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(g^* \rightarrow b)</td>
<td>(\text{[o, a, i, C]})</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(g^* \rightarrow d)</td>
<td>(\text{[e]})</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(g^* \rightarrow ph)</td>
<td>(\text{[o, a, i, C]})</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(g^* \rightarrow th)</td>
<td>(\text{[e]})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uto-Aztecan</td>
<td>O’Tooleham</td>
<td>(k^* \rightarrow b)</td>
<td></td>
<td>[4, 5]</td>
</tr>
<tr>
<td></td>
<td>Mountain Pima</td>
<td>(\text{[C} C})</td>
<td></td>
<td>[2]</td>
</tr>
<tr>
<td></td>
<td>Northern Tepehuan</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muskogean</td>
<td>Choctaw</td>
<td>(k^* \rightarrow b)</td>
<td>(\text{[C} C})</td>
<td>[1]</td>
</tr>
<tr>
<td></td>
<td>Creek-Seminole</td>
<td>(k^* \rightarrow p)</td>
<td></td>
<td>[1]</td>
</tr>
</tbody>
</table>

Table 2: Confusion matrix showing speaker \([\text{p}]\) responses to \([\text{kw}]\) stimuli.

<table>
<thead>
<tr>
<th>Responses</th>
<th>pe</th>
<th>pi</th>
<th>po</th>
<th>Other Responses</th>
</tr>
</thead>
</table>
| Speaker 1F
Stimulus | kwe | 0.00 | 0.07 | 0.00 | 1.00 |
| Speaker 1M
Stimulus | kwe | 0.00 | 0.00 | 0.00 | 1.00 |
| Speaker 2F
Stimulus | kwe | 0.00 | 0.06 | 0.00 | 1.00 |
| Speaker 2M
Stimulus | kwe | 0.00 | 0.21 | 0.16 | 0.86 |
| Speaker 3M
Stimulus | kwe | 0.08 | 0.13 | 0.16 | 0.92 |

References