Perceptual confusability of French vowels

Kathleen C. Hall* and Elizabeth V. Hume

*Corresponding author’s address: Linguistics, University of British Columbia, 2613 West Mall, Vancouver, V6T 1Z4, BC, Canada, kathleen.hall@ubc.ca

The confusability of sounds is argued to both reflect phonological structure (e.g., Boomershine et al. 2008) and be a source of phonological variability and change (e.g., Ohala 1981, Hume 1998). We present the results of a perception task in which 25 Parisian French-speaking participants identified the French vowels [ɪ e ɛ y ø œ ə a u o ɔ ɔ̃ ɛ̃ ɑ̃], or ∅, in an aC_Ca context, using standard orthography in key words. We can therefore determine which vowels are most confusable with each other (and thus likely to be the target for either mergers or dissimilatory processes) and which are most confusable with zero (and thus likely to be the target of processes such as deletion, assimilation, and metathesis). Results show high accuracy for [a i y u]; some degree of confusability within the nasal vowels; high confusability rates within the mid-front rounded vowels; and a tendency for zero to be confused with one of the mid-front rounded vowels. These results align with observed phonological patterns in French.

Published by the Acoustical Society of America through the American Institute of Physics
INTRODUCTION

The perceptual salience of a given sound has been proposed to be a source of phonological variability and change and thus reflected in phonological structure. In particular, a weakly distinct or confusable sound has been claimed to be prone to, for example, neutralization, reduction, assimilation or metathesis, especially insofar as the listener is a source of sound change (e.g., Ohala 1981; Flemming 1995; Jun 1995; Steriade 2001; Wilson 2001; Blevins 2004; Hume 2003, 2008). Perceptual salience can be influenced not only by the sound's inherent phonetic cues and the context in which it occurs, but also by the phonological status of the sound in relation to other sounds in the language: allophonic sounds tend to be perceived as more similar and hence more confusable than contrastive ones (e.g., Trubetzkoy 1969, Whalen et al, 1997, Kazanina et al. 2006, Boomershine et al. 2008, Johnson & Babel 2010).

In this study we investigate the confusability of vowels in French as a means of testing these claims.

METHODS

Stimuli

Stimuli were pseudo-words of the form [aCVCa], produced by a linguistically trained male native speaker of Continental French in a sound-attenuated room at the University of Arizona. The consonants were one of [b...d], [b...g], [d...b], [d...q], [g...b], or [g...d]. There was either no vowel between the consonants, or the medial vowel was one of [i e ɛ y ø e a u o o ɔ ɛ õ ɔ ɑ]. The French vowel commonly referred to as "schwa" and written orthographically as <e> as in le ‘the’; its quality varies between [æ] and [a] depending on speaker and region. The pseudo-words were placed in the carrier phrase, Il voit cet ___. ‘he sees this ___.’ Words were presented in standard French orthography and blocked by vowel; at the beginning of each block, a real French word containing the vowel in question was presented as an example (e.g. Il voit cet abida. (comme dans nid)). Each sentence was presented (and recorded) three times, in immediate succession, for a total of 270 tokens (6 consonantal contexts x 15 vowels x 3 repetitions = 270). One version of each pseudo-word was selected manually, taking into consideration similarity of intonation and duration across tokens, fluency, and clarity of production. The target pseudo-words were extracted from the carrier phrase, but tokens were not otherwise manipulated. Thus, there were a total of 90 pseudo-word stimuli. Additional results for the stimuli containing no medial vowel presented in a different test block (not otherwise reported here) are also included below; thus, each participant responded to 96 tokens.

Task

Participants wore headphones and sat in front of a computer screen in a sound-attenuated booth. They were asked to listen to a randomized series of pseudo-words, presented one at a time using the experimental software E-Prime 2.0 (Psychology Software Tools, Pittsburgh, PA), and to identify the vowel, if any, that they heard between the consonants. The subject clicked either on ‘no vowel,’ or on one of the fourteen words that illustrated the pronunciation of the vowels being presented, e.g. nid ‘nest’ ([i]), neuf ‘nine’ ([œ]), noeu ‘knot’ ([o]), noce ‘wedding’ ([ɔ]), nos ‘our’ ([o]), etc. (the IPA symbols and English translations did not appear on the screen). As noted above, an additional vowel, commonly referred to as French “schwa” as in the word ne ‘not,’ was also offered as a choice. Subjects first participated in a training block in which they heard each vowel type once and had to identify the example word (with feedback); this was repeated until they identified every vowel correctly. In the test block, the task was identical, but there was no feedback and six examples of each vowel type (in each of six consonantal contexts) were given.

Participants

Twenty-five native speakers of continental French (5 men, 20 women; aged 19-45) participated in the experiment. Participants were paid 10€ each for their participation. All participants were tested in Paris, France, and all aspects of the experiment were conducted in French.
RESULTS

Table 1 shows the results for identification accuracy; that is, the percentage of time that a particular stimulus (listed in the rows) was identified as a given vowel (listed in the columns).

<table>
<thead>
<tr>
<th>Correct Response</th>
<th>Ø</th>
<th>'e'</th>
<th>[o]</th>
<th>[œ]</th>
<th>[ɛ]</th>
<th>[ɔ]</th>
<th>[u]</th>
<th>[y]</th>
<th>[i]</th>
<th>[a]</th>
<th>[ẽ]</th>
<th>[ɔ]</th>
<th>[ẽ]</th>
<th>??</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ø</td>
<td>78</td>
<td>11</td>
<td>3.7</td>
<td>4.3</td>
<td>.33</td>
<td>2</td>
<td>.0</td>
<td>.33</td>
<td>.33</td>
<td>.33</td>
<td>.33</td>
<td>.33</td>
<td>.33</td>
<td>.33</td>
</tr>
<tr>
<td>'e'</td>
<td>37</td>
<td>38</td>
<td>25</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
</tr>
<tr>
<td>[o]</td>
<td>27</td>
<td>29</td>
<td>45</td>
<td>.33</td>
<td>.33</td>
<td>.33</td>
<td>.33</td>
<td>.33</td>
<td>.33</td>
<td>.33</td>
<td>.33</td>
<td>.33</td>
<td>.33</td>
<td>.33</td>
</tr>
<tr>
<td>[œ]</td>
<td>2.0</td>
<td>31</td>
<td>4.1</td>
<td>.25</td>
<td>.25</td>
<td>.25</td>
<td>.25</td>
<td>.25</td>
<td>.25</td>
<td>.25</td>
<td>.25</td>
<td>.25</td>
<td>.25</td>
<td>.25</td>
</tr>
<tr>
<td>[ɛ]</td>
<td>.67</td>
<td>1.3</td>
<td>.71</td>
<td>.27</td>
<td>.27</td>
<td>.27</td>
<td>.27</td>
<td>.27</td>
<td>.27</td>
<td>.27</td>
<td>.27</td>
<td>.27</td>
<td>.27</td>
<td>.27</td>
</tr>
<tr>
<td>[ɔ]</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>[u]</td>
<td>.67</td>
<td>1.3</td>
<td>2.7</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>[y]</td>
<td>.67</td>
<td>99</td>
<td>99</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
</tr>
<tr>
<td>[i]</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>[a]</td>
<td>67</td>
<td>99</td>
<td>99</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
<td>.67</td>
</tr>
<tr>
<td>[ẽ]</td>
<td>.67</td>
<td>95</td>
<td>95</td>
<td>4.7</td>
<td>4.7</td>
<td>4.7</td>
<td>4.7</td>
<td>4.7</td>
<td>4.7</td>
<td>4.7</td>
<td>4.7</td>
<td>4.7</td>
<td>4.7</td>
<td>4.7</td>
</tr>
<tr>
<td>[ɔ]</td>
<td>.67</td>
<td>8.0</td>
<td>91</td>
<td>8.0</td>
<td>8.0</td>
<td>8.0</td>
<td>8.0</td>
<td>8.0</td>
<td>8.0</td>
<td>8.0</td>
<td>8.0</td>
<td>8.0</td>
<td>8.0</td>
<td>8.0</td>
</tr>
</tbody>
</table>

The only vowel that was always identified correctly was [i]; note that in addition to a 100% accuracy rate on identifying [i] tokens, participants also were entirely accurate with their use of the [i] label—that is, they never used it as a response for any vowel other than [i]. The vowels [a] and [y] were also identified correctly most of the time (≥99% accuracy each), although the [y] label in particular was erroneously used to label [u] tokens as well.

The vowels with the lowest accuracy rates were the mid-front rounded vowels: lax [œ], tense [o], and orthographic ‘e’ (French “schwa”); recall that the pronunciation of the latter vowel varies between [œ] and [o], depending on speaker and dialect. Of these, orthographic ‘e’ was correctly identified most often (37% accuracy), followed by [œ] (29%) and [œ] (25%). These three vowels were highly confusable with each other, with all three being identified as ‘e’ at least 27% of the time. [o] and [œ] were more often mis-identified as each other than they were correctly identified.

The other particularly poorly identified vowel was [ɔ], which was correctly identified only 52% of the time; it was most often mis-identified as [o]. Note that this confusion is asymmetrical; while [ɔ] was in fact the most common choice of label for [o] when it was mis-identified, mis-identification of [o] happened only 19% of the time as compared to 48% of the time for [ɔ].

As can be seen from the clustering of incorrect responses in the upper left-hand corner of Table 1, the most common incorrect responses involved the mid-front rounded vowels. That is, these were the labels that were used most often when vowels were mis-identified, and they were used to label all vowels except for the “corner” vowels [i, y, u, a] and the nasalized vowels [ã, 3, õ]. Furthermore, when no vowel at all was present, a mid-front rounded vowel was mistakenly identified as being there 19% of the time (with 22% total mis-identification of Ø).

The identification of nasalized vowels themselves was relatively accurate (ranging from 87 to 95% correct), and these were most often confused with each other when they were mis-identified. Both [ɔ] and [ẽ] were mis-identified as [ã], while [ã] itself was the least accurately identified vowel of the three, being most commonly mis-identified as [œ].
DISCUSSION

These results make sense if both acoustic and phonological facts are taken into consideration. The vowels with the highest accuracy rates are those at the corners of the acoustic vowel space—the high, front vowels [i] and [y] and the low vowel [a]. It is reasonable to assume that the more disperse formant characteristics of these vowels make them easier to distinguish (e.g., Lindblom 1986, 1990; Flemming 1995). Similarly, nasalization seems to be a strong cue to vowel identification, as there were very few mistakes among the nasal vowels, and very few non-nasal vowels were mis-identified as being nasal.

At the same time, the patterns of confusion among vowels that were mis-identified seem to be attributable at least in part to phonological factors. Tense and lax pairs of vowels ([e]/[ɛ], [o]/[ɔ], and [ɔ]/[œ]; marked by dashed lines in Table 1) were far more often confused with each other than pairs of vowels that differ in some single feature other than tenseness (e.g., rounding, [i]/[y] or [e]/[œ]; or height, [i]/[ɛ] or [u]/[o]). The increased confusability between tense/lax vowels is likely due in part to their phonological patterning as members of each pair are largely non-contrastive. Rather, tense/lax pairs generally occur in complementary distribution in French, with the tense vowel occurring in open syllables and the lax vowel in closed syllables (e.g., Léon et al. 1992). There are some minimal pairs in which tense/lax pairs contrast, e.g. allé [ale] ‘gone’ vs. allait [ale] ‘was going’, rauque ‘hoarse’ [rok] vs. roc ‘rock’ [rok], or jeûne ‘fast’ [jun] vs. jeune ‘young’ [jenis]. Interestingly, the context of the stimuli in the experiment would most likely be parsed as having the vowels in minimal pairs in which tense/lax pairs contrast, e.g., Lindblom 1986, 1990; Flemming 1995

Furthermore, the high degree of confusability among the mid front rounded vowels makes sense in the context of the processes of epenthesis and deletion in French (see Noske 1993, Carton 1999, Hume et al. 2013). In particular, the vowel that is inserted (e.g. bien sûr(e) ‘certainly’) or deleted (e.g. pr(e)tit ‘small, masc.’) varies between [o] and [a] (Landick 1995; Adda-Decker et al. 1999; Féry 2003; Fougéron et al. 2007). The interchangeability of these two vowels phonologically, and the observation that both are confusable with ◊ may lead to their perceptual confusability. Further, the results are consistent with the claim that the vowel that is epenthized or deleted has low salience, measured in the present context as being confusable with ◊ (e.g., Steria 2001, Hume et al. 2013, Hume and Mailhot 2013). In addition to reflecting current phonological patterns, the results reported above may also shed light on future changes in the French phonological system. In particular, to the extent that vowel confusability is a source of phonological variability, French vowels that are highly confusablae with each other are predicted to be less stable and more likely to undergo change less confusablae vowels.

CONCLUSION

The identification of French vowels by native listeners in this study provides support for the view that both phonetic and phonological factors contribute to the confusability of vowels. While vowels that are highly dispersed acoustically tend to be accurately identified, less dispersed vowels are more confusablae. The latter vowels correspond to those vowels that are weakly contrastive with each other. The results also support the claim that the vowel that patterns asymmetrically as a language's default vowel in epenthesis or deletion is highly confusablae with ◊.

ACKNOWLEDGMENTS

We are especially grateful to Lionel Mathieu, Annie Rialland, Rory Turnbull, and Adam Ussishkin for help in conducting this research. All errors of course remain our own.

REFERENCES


Fougeron, Cécile, Cédric Gendrot, and A. Bürki. 2007. On the phonetic identity of French schwa compared to /ø/ and /oe/. Paper read at 5èmes Journées d'Études Linguistiques (JEL), at Nantes, France.


Hall, Kathleen Currie. 2009. *A probabilistic model of phonological relationships from contrast to allophony*. Doctoral dissertation, Linguistics, The Ohio State University, Columbus, OH.


