ABSTRACT
A psychoacoustic experiment was carried out to establish the perceptual correlates of a vowel contrast neutralization (European French /e/ and /ɛ/) observed in production. The results show that subjects categorized the same synthetic vowel continuum into 3 categories (/i/, /e/, and /ɛ/) for CV tokens; and into 2 categories (/i/ and /ɛ/) for CVC tokens. This finding provides an explanation for the fact that francophones usually replace the last vowel of English "happy" with /ɛ/, and the last vowel of English "presented" with /i/, a result that cannot be explained by comparing the physical attributes of these English vowels and those of the French vowels that are used to replace them. Rather, it appears that phonotactic constraints may play an important role in the perception of second-language speech sounds.

1. INTRODUCTION
In European French, the opposition between the two vowel phonemes /e/ and /ɛ/, which is actualized in free syllables (CV), is neutralized in checked syllables (CVC), where only /ɛ/ can occur. Thus, while both /e/ and /ɛ/ can occur in free syllables (as in fŽe/fe/ and fai̱t/fe/), only /ɛ/ can occur in checked syllables (as in fer and faire, both pronounced /feːr/). The purpose of the study reported here was (a) to establish the perceptual correlates of the vowel contrast neutralization of the French vowels /e/ and /ɛ/ observed in production; and (b) to document the effect of phonotactic constraints on the perception and production of second-language (L2) speech sounds.

2. PROCEDURES
2.1. Stimulus set
A synthetic continuum covering the acoustic range of the front unrounded vowels /i/, /ɛ/, and /ɛ/ was created with Klatt's [3] cascade/parallel speech synthesizer by varying the frequency values of the first and second formants (F1 and F2) and adjusting the F1 and F2 transitions in CV and CVC syllables, where V represents one of the synthesized vowel stimuli and C represents the consonant /s/. Figure 1 shows the F1 and F2 frequency values.

2.2. Subjects and experimental task
Sixteen adult native speakers of European French with normal hearing took part in the experiment. Their task consisted of identifying as one of the 3 vowels, /i/, /ɛ/, or /ɛ/, each token that was presented to them through good quality earphones on a microcomputer, by means of a perceptual test program developed by the authors. On each trial, the program randomly selected without replacement a single stimulus from the set of 320 tokens (10 repetitions of each point on the continuum for both the CV and the CVC environments) and played it twice with a 20 millisecond-second silence interval. The program waited until the subject had responded before presenting the next item.

Table 1. F1, F2 and transition values.

<table>
<thead>
<tr>
<th>Stimulus</th>
<th>F1 (Hz)</th>
<th>F1 Trans.</th>
<th>F2 (Hz)</th>
<th>F2 Trans.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>250</td>
<td>307</td>
<td>2200</td>
<td>1828</td>
</tr>
<tr>
<td>2</td>
<td>285</td>
<td>322</td>
<td>2140</td>
<td>1805</td>
</tr>
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<td>3</td>
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<tr>
<td>6</td>
<td>373</td>
<td>360</td>
<td>1990</td>
<td>1748</td>
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<td>7</td>
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<tr>
<td>16</td>
<td>556</td>
<td>443</td>
<td>1660</td>
<td>1623</td>
</tr>
</tbody>
</table>

2.3. Hypothesis
It was hypothesized that three vowel categories would be perceived (as /i/, /ɛ/ or /ɛ/) in free syllable tokens, and that
only two categories (/i/ and /e/) would be perceived in checked syllables, i.e., that the phonotactic constraint that governs the production of these vowels would also govern their perception.

3. RESULTS

Figures 2 and 3 represent the identification functions of one of the subjects for the CV and CVC contexts, respectively. The pattern displayed by these identification functions was the same for all subjects, with only minor variations. Figure 2 shows that in free syllables, subjects categorized the vowel continuum into three well-defined vowel categories (/i/, /e/, and /e/). In checked syllables (Figure 3), they categorized it into two categories only (/i/ and /e/).

![Figure 2. CV Identification Functions.](image)

![Figure 3. CVC Identification Functions.](image)

This finding is in contradiction with the usual phonological description that posits an affinity ("archiphoneme" in Praguian linguistics) between /e/ and /e/. Instead, it appears that most of the perceptual shift associated with the free and checked environments is between /i/ and /e/, not between /e/ and /e/.

4. DISCUSSION

4.1. Phonotactics and speech perception

For the subjects who took part in the experiment described above, it appears that perception parallels production in that the contrast /e:e/ is neutralized in perception as it is in production. In particular, it is clear that for these speakers, the perception of vowel segments in the front vowel series is governed by phonotactic constraints. This finding corroborates the results of previous studies that found that identification of phonological categories may be influenced and overridden by salient phonological context information [4, 5, 8, 9].

Figures 2 and 3 also provide a striking argument against the notion of “uncommitted space” usually encountered in discussions of the perception of second-language speech sounds [8]. It is clear that each of the three vowel categories considered here (/i/, /e/, and /e/) extends as far as the limits of the next category or categories even when one of these categories does not occur in a particular phonological context. Given the fact that the same phonological category can have different acoustical realizations in different environments (phonetic, phonological, or dialectal) one can expect the lack of uncommitted space between adjacent categories to result in flexible acoustic areas for individual phonological categories and in shifting perceptual boundaries between adjacent categories. Such acoustic area changes and boundary shifts are likely to be larger in cases of neutralization, when one or more categories that occur together in a given environment do not co-occur in some other context(s). The next section will investigate the relevance of such large acoustic changes and boundary shifts to our understanding of L2 sound replacements.

4.2. Implications for the perception of L2 speech sounds and for L2 sound replacements

In order to understand some of the potential effects of the boundary shift described above on the perception of second-language speech sounds, let us assume one or more L2 (target) vowel(s) with such F1 and F2 frequency values that they fall between stimuli 6 to 10 on the continuum described above. Such vowels would be perceived (and one can assume pronounced) by a French native speaker as [e] in free syllables and as [i] in checked syllables.

This is in fact what happens for the vowel sounds occurring in the last syllable of the English words “happy” and “presented.” In many dialects of English, the acoustic characteristics of these two vowels are very close to each other [6] and most of their realizations fall between stimuli 6 and 10 on the continuum described above. Figure 4 provides an explanation for the fact that francophones speaking English with a French accent often pronounce these two words as “happy” [apavr] and “presented” [presentrd], respectively.
It is clear that the productions [ap] and [pzentIid] for English “happy” and “presented” by French speakers are the result of how these two words—and more specifically their last vowels—are perceived by French speakers. These two vowels are perceived as belonging to two different categories in spite of their acoustic similarity, because one occurs in a free syllable and the other in a checked syllable. The last vowel of English “happy” is processed by French listeners as per the identification functions in the top half of Figure 4, i.e., the identification functions that pertain to the front unrounded vowel series as it is categorized by French speakers in free syllables.

On the other hand, the last vowel of English “presented” is processed by French listeners as per the identification functions in the bottom half of Figure 4, i.e., the identification functions that pertain to the front unrounded vowel series as it is categorized by French speakers in checked syllables.

Other examples from L2 sound replacements that reflect L1 phonotactic constraints come to mind. Thus, the English voiceless interdental fricative /ʃ/ is usually pronounced—and one can assume perceived—as /s/ by European French speakers, except when it is followed by /a/, in which case it is usually pronounced /ʃ/. This context-dependent sound replacement is probably the result of the fact that in French, /s/ does not occur before /a/, but /ʃ/ does. Thus, of the fricatives available to French listeners in prevocalic position, /s/ appears to be the most suitable approximation—or replacement—for English /θ/. On the other hand, before a following /ɪ/ or /ɛ/, the only voiceless fricative available to French listeners is /ʃ/, and it is used (instead of /s/) as the replacement for English /θ/ in that context.

4.3. Implications for L2 pronunciation instruction

These findings have implications for L2 pronunciation instruction. It is generally agreed that native-like perception of L2 sounds and sound categories is a prerequisite to an acceptable (i.e., native-like) pronunciation of those sounds. Previous research has also shown that L2 pronunciation instruction materials must take into account the characteristics of the learner’s sound system [1, 2, 4]. For example, both anglophones and speakers of Portuguese learning French need to acquire an additional high vowel category, because French has three high vowels (/i, y, u/), while English and Portuguese have only two (/i, u/). However, because untrained Portuguese speakers perceive French /y/ as a member of their /i/ category, while English speakers perceive it as a member of their /u/ category, auditory training materials need to contrast /i/ and /y/ for Portuguese speakers and /u/ and /y/ for anglophones [7].

The results of the present study further suggest that, because perception of phonetic segments appears to be shaped by phonotactic constraints, auditory training materials for L2 pronunciation instruction materials must be context-dependent and reflect salient L1 phonotactic constraints. Specifically, the results of this study show that to facilitate their acquisition of the English front vowels, French learners must be presented with target materials that clearly illustrate the contrasts /i: i: e:/ in checked syllables, an environment in which only two front unrounded vowels (/i/ and /ɛ/) occur in French.

5. CONCLUSIONS

The results of the present study suggest that understanding the process of phonetic interference requires that attention be paid not only to L1 phonological categories, but also to their distribution (i.e., their pattern of occurrence and non-occurrence in various phonetic environments). The realization that the perception of L2 phones is highly context-sensitive points to the need for fine-grained perceptual tests in our quest to understand L2 sound replacements and the phenomenon of foreign accent. Such tests—along with equally fine-grained acoustic and articulatory analyses of L1 and L2 speech sounds—should yield accurate descriptions of the perceptual and articulatory behaviors of L2 learners in the various relevant environments. They should also lead to a better understanding of phonetic change and of speech perception and production in general.

REFERENCES


