EFFECTS OF L1 PHONOTACTIC CONSTRAINTS ON L2 SPEECH PERCEPTION

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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 /e/, 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 *fée* /fe/ and *fait* /fɛ/), only /ɛ/ can occur in checked syllables (as in *fer* and *faire*, both pronounced /fɛʁ/). 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/, /e/, 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 values for the centre of the vowel of each stimulus on the continuum. For each stimulus, formant transitions progress linearly from the transition frequency value given in Table 1 to the vowel centre frequency value. The total number of stimuli on the continuum was 32, 16 each for the CV and the CVC contexts.

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/, /e/, 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.

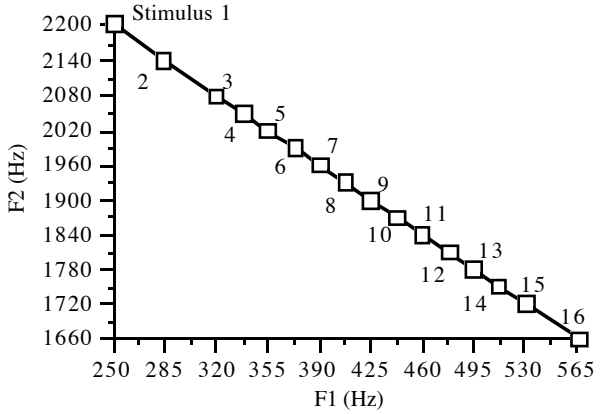

Figure 1. F1 and F2 frequency values.

Stimulus	F1 (Hz)	F1 Trans.	F2 (Hz)	F2 Trans.
1	250	307	2200	1828
2	285	322	2140	1805
3	320	337	2080	1782
4	338	345	2050	1771
5	355	352	2020	1760
6	373	360	1990	1748
7	390	367	1960	1737
8	408	375	1930	1725
9	425	382	1900	1714
10	443	390	1870	1703
11	460	397	1840	1691
12	478	405	1810	1680
13	495	412	1780	1668
14	513	420	1750	1657
15	531	428	1720	1646
16	566	443	1660	1623

Table 1. F1, F2 and transition values.

2.3. Hypothesis

It was hypothesized that three vowel categories would be perceived (as /i/, /e/ or /ɛ/) in free syllable tokens, and that

only two categories (/i/ and /ɛ/) 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 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 /ɛ/). In checked syllables (Figure 3), they categorized it into two categories only (/i/ and /ɛ/).

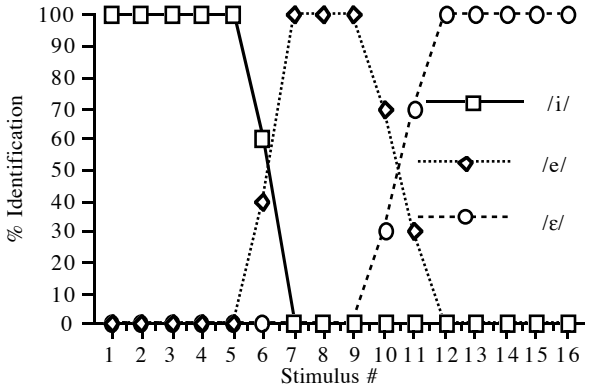

Figure 2. CV Identification Functions.

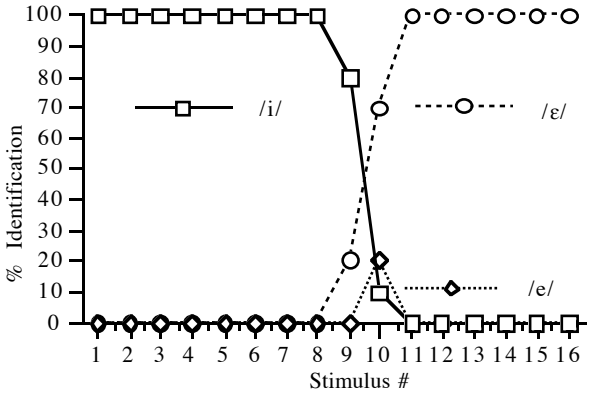

Figure 3. CVC Identification Functions.

A comparison of the identification functions displayed in Figures 2 and 3 also reveals that the perceptual area for /ɛ/ is practically the same for free and checked syllables, with the boundary between /e/ and /ɛ/ located between the 10th and 11th stimuli in CV syllables, and the boundary between /i/ and /ɛ/ located between the 9th and 10th stimuli in CVC syllables. What varies the most is the area for /i/; the boundary between /i/ and /e/ is located around the 6th stimulus in CV syllables, and the boundary between /i/ and /ɛ/ is located between the 9th and 10th stimuli in CVC syllables. This finding is in contradiction with the usual phonological description that posits an affinity ("archiphoneme" in Praguian linguistics) between /e/ and /ɛ/. 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 /ɛ/.

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:ɛ/ 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 segments may be influenced and overriden 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 /ɛ/) 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" [ap̬e] and "presented" [pʁezɛnt̬id], respectively.

It is clear that the productions [ape̱] and [pʁezɛnti̱d] 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.

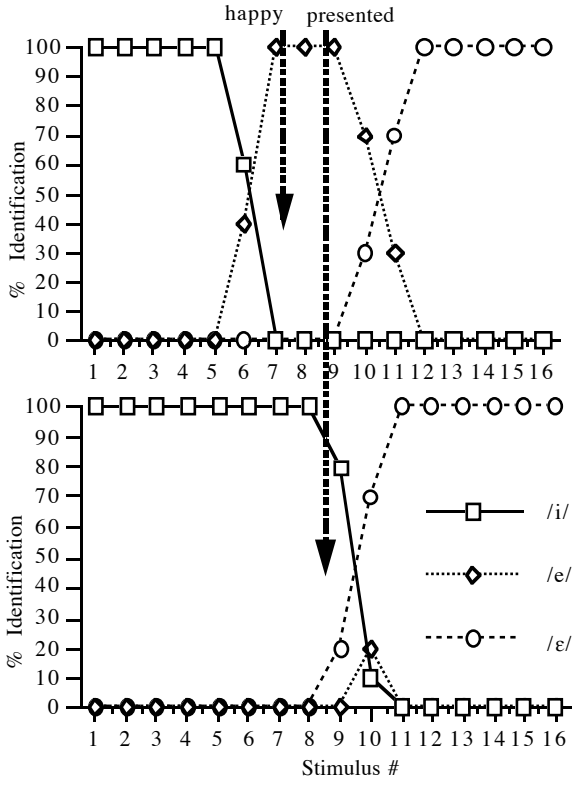

Figure 4. Perception of the last vowels of English "happy" and "presented" by French speakers.

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 /θ/ is usually pronounced--and one can assume *perceived*-- as /s/ by European French speakers, except when it is followed by /ɹ/, in which case it is usually pronounced /f/. This context-dependent sound replacement is probably the result of the fact that in French, /s/ does not occur before /ʁ/, but /f/ 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 /ʁ/, the only voiceless fricative available to French listeners is /f/, 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: ɛ/ 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.

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