The Interlingual Identification of Spanish and English Vowels: Orthographic Evidence
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When someone who is learning a second language (L2) produces a sound in the L2 using a familiar, native-language (L1) category, the L2 sound is said to have been "identified with" an L1 sound. Although interlingual identification exerts a powerful influence on L2 pronunciation, it is still poorly understood. Orthographic classification was used here to assess the interlingual identification of Spanish and English vowels. Sixty native speakers of Spanish in three experiments judged the vowels /i/, /u/, /æ/, and /æ/ in multiple tokens of English words ("beat", "bit", "bet", "bat") spoken by ten native speakers of American English. The subjects labelled each English vowel by circling one of the five letters used to spell the vowel phonemes of Spanish (viz. <i>, <e>, <a>, <o>, <u>) or by circling "none" if they thought they had heard a vowel not found in Spanish. Subjects who spoke English as an L2 used the "none" label more often than did Spanish monolinguals, suggesting that L2 learning heightens bilinguals' awareness of cross-language phonetic differences. Experienced Spanish speakers of English did use the "none" label more often than did inexperienced subjects (42% vs. 18%). A few subjects used the "none" label consistently for /æ/ and /i/, suggesting that they may have regarded these vowels as "new" (i.e., non-Spanish). However, the group data provided little support for the hypothesis that the adult Spanish learners of English treated either /æ/ or /i/ as new. The great majority of subjects, even those highly experienced in English, identified English /æ/ with their Spanish /a/.

It is widely believed that adults will inevitably speak a language learned after childhood with a foreign accent (Lenneberg 1967). Scovel (1969, 1988) claimed that foreign accents occur because of lost "plasticity" in "neuropsy-
chological mechanisms" deriving from the completion of cerebral lateralization at around the age of 12 (see also Patkowski, 1990; but cf. Flege, 1987a, Flege & Fletcher, submitted). Precisely which aspect(s) of speech learning changes with age has not been identified by advocates of the critical period hypothesis, but it is often implied that processes that underlie sensorimotor learning may become less effective as the result of neural maturation (Sapon 1952; Scovel, 1988, p. 62). Some L2 production errors do, in fact, seem to have a motoric basis (Flege, 1988c; Flege, McCutcheon, & Smith, 1987), but many others may arise from the inaccurate perception of L2 sounds. The results of certain speech perception experiments suggest that adult learners of an L2 do not have representations for some sounds in an L2, at least not at first (e.g. Miyawaki et al., 1975. Mochizuki, 1981; Sheldon & Strange 1982). For other L2 sounds, adult learners have been observed to perform consistently, albeit not precisely like native speakers of English. In these instances, the adult learners appear to make use of native language (L1) representations that differ from those of native speakers (e.g. Flege & Hillenbrand, 1985, 1987; Flege & Eefting, 1986; Flege, 1989b; Flege & Wang, 1990).

It is generally agreed that speech perception is an obligatory process. L2 learners attempt to make perceptual sense of the sounds making up L2 words, regardless of whether or not they have an accurate (i.e. native-like) perceptual representation for the L2 sounds. Unless they have managed to establish phonetic categories for L2 sounds (see Flege, 1990; in press, a, b), adult learners will tend to identify unfamiliar L2 sounds in terms of an L1 category (Weinreich, 1953; Wode, 1977, 1978; see also Butcher, 1976). This process, called "interlingual identification", often amounts to fitting square pegs into round holes. Adult learners' perceptual "errors" may not be evident, however, because they often comprehend the L2 in the absence of accurate phonetic perception by exploiting semantic context and their knowledge of the world.

The occurrence of perceptual errors or mismatches in the processing of L2 words may be inferred, however, from how adult learners pronounce the L2. When an unfamiliar L2 sound has been identified with an acoustically

1 Flege (1988c) and Flege et al. (1987) examined the production of the word-final English /p/—/b/ contrast by native speakers of Chinese. A significant difference in peak oral air pressure between English /p/ and /b/ suggested that the Chinese subjects produced these sounds with different laryngeal articulations. However, they failed to sustain closure voicing in /b/ for as long as native speakers, apparently because they had not learned to enlarge the supraglottal cavity actively during labial closure for /b/.

2 The term "sound", as used here, refers to a class of phones that can be used to contrast meaning. It is a terminological convenience that obviates the need to draw a distinction constantly between the phonetic and phonemic levels. For an exposition of this theoretically important distinction, see Flege (in press, n).
different sound in the L1, the L1 sound may be used in place of the L2 sound (Valdman, 1976). Table 1 summarizes six studies that have reported on vowel substitution errors in Spanish-accented English. The target vowels in this table are those examined in the present study (viz. /i/, /i/, /e/, and /æ/). The six studies differed in many ways, including the L2 experience of the Spanish subjects examined, speech materials, and elicitation techniques. It is unclear in many instances whether the “substitutes” reported were English vowels, Spanish vowels, or a phonetic approximation of the intended English target vowel. Several conclusions can nevertheless be drawn from Table 1: (1) Spanish speakers usually produce English /i/ as an [i]-quality vowel; (2) if they mispronounce /i/, it is usually as an [i]-quality vowel; and (3) if they mispronounce /æ/, it is as an [e]-quality vowel.

One might also conclude from the data in Table 1 that Spanish learners of English are more variable in their mispronunciation of /æ/ than that of other front, monophthongal English vowels. In producing /æ/, they manifest both mid-vowel ([e], [e'], [e]) and back-vowel ([a]) substitutes. The use of multiple L1 substitutes for an unfamiliar L2 sound, especially in early stages of learning (Hammarberg, in press), may mean that an unfamiliar L2 sound has been judged to be perceptually equidistant from two or more L1 sounds. It might also be taken to mean that a particular L2 vowel does not have a readily identifiable counterpart in the L1.

None of the five Spanish vowels (/i, e, a, o, u/) seems to match any of the 15 vowels of English. Flege (1989a) found that the tongue is lower for English /i/ and /u/ than for the corresponding vowels of Spanish, and the tongue is lower for English /a/ than for Spanish /a/ (suggesting a narrower pharyngeal cavity for the English vowel). English /oʊ/ and especially /eɪ/ are more diphthongized than Spanish /e/ and /o/ (Stockwell & Bowen, 1965;

### Table 1
Vowel Substitution Errors in Spanish-Accented English

<table>
<thead>
<tr>
<th>Target English Vowel</th>
<th>Most Frequent Substitute Reported</th>
<th>Other Reported Substitutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>/i/</td>
<td>[i]'</td>
<td></td>
</tr>
<tr>
<td>/i/</td>
<td>[e]'</td>
<td>[e]'</td>
</tr>
<tr>
<td>/e/</td>
<td>[e]'</td>
<td>[e]'</td>
</tr>
<tr>
<td>/æ/</td>
<td>[æ]'</td>
<td>[æ]' [e]' [e]'</td>
</tr>
</tbody>
</table>

1 Brennan & Brennan (1981);
2 Hammond (1986);
3 Flege (1990);
4 Amastae (1978);
5 Ornstein (1974);
6 MacDonald (1989).
Dalbor, 1980; Quiles, 1981; Flege, 1989a). Also, English vowels are generally longer than Spanish vowels because they are lengthened more under stress and in pre-pausal position (Delattre, 1966).

Wode (1977, 1978) suggested that there is a threshold beyond which an L2 sound will be recognized as distinct from any sound in the L1. A distinction between "new" L2 sounds and those that are merely "similar" to sounds in the L1 has been drawn by researchers for several decades (Delattre, 1964, 1969; Brière, 1968), but no satisfactory metric now exists for determining whether an L2 vowel will be treated as new or similar (see below).

Unlike consonantal sounds, vowel sounds are discriminated readily even if they are not classified differently. One obstacle to classifying L2 vowels as new vs. similar has been uncertainty as to whether the distance between vowels in two languages is judged in terms of an auditory, phonetic, or phonemic metric (see below). The question raised in this study was whether Spanish speakers would come to recognize that any of the front, monophthongal vowels of American English are new (i.e. non-Spanish).

**Orthographic Classification**

The present study examined patterns of interlingual identification that might be responsible for vowel production errors like those in Table 1. Native Spanish subjects were asked to label English vowels with one of the letters used to write the five vowel phonemes of Spanish (i.e., /i/, /e/, /a/, /u/). The vowels they were asked to label /i/, /e/, /a/, /u/ occurred in CVC words spoken by native speakers of American English.

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1 Flege (in press, a) discussed methods that might be used to operationalize the distinction between new and similar L2 sounds. A similar L2 sound may be defined as a sound that is represented by the same IPA symbol as a sound in the L1, provided it can be shown to differ auditorily from the corresponding L1 sound. New sounds, on the other hand, may be defined as L2 sounds that are represented by an IPA symbol not used for any sound in the L1 (and, of course, which differ auditorily from the nearest L1 sound). Problems with this approach do exist, however, especially with the "symbol" test (see, e.g., Footnote 4).

4 Phoneticians have long debated whether transcriptions of vowels should be detailed enough to represent any *auditory detectable* difference between vowels or just differences that underlie word contrasts in a particular language. It is uncertain how many different distinct vowel "types" there are. Ladefoged (1989) estimated that an expert phonetician might be capable of identifying as many as 200 vowels in absolute terms.

3 The use of an auditory-based metric to evaluate the relationship between vowels in two languages cannot be discounted. Spanish and English listeners in the Flege et al. (in preparation) study gave much the same responses to pairs of vowels that were labelled differentially. For example, both groups rated Spanish /i/-/a/ pairs to be more dissimilar than /i/-/e/ pairs; and both groups rated the /i/-/e/ pairs as more dissimilar than /e/-/a/ pairs. Such agreement between groups implies the existence of a universal auditory-based distance metric. Interlingual comparisons based on auditory representations would be expected to differ at times from those based on representations of phonetic quality (see, e.g., Klatt, 1987, Figure 34).
Orthographic classification was a plausible technique for investigating interlingual identification because Spanish vowels (unlike those in English) stand in a one-to-one relationship with letters. It has been used successfully by Wiik (1965, cited by Flege, 1988b) to examine the classification of English vowels by native speakers of another language with "phonemic" spelling (i.e. Finnish).

Subjects in the present study were also permitted to use the label "none". This label provided a means for determining whether any of the English vowels were judged to fall outside the bounds of the Spanish vowel system. Results obtained by Butcher (1976) suggested that adult subjects can use "none" appropriately. In that study, French and English subjects were asked to label a set of cardinal vowels that differed to varying degrees from L1 vowels. The English but not the French subjects used "none" frequently to label front rounded (/ɪ/, /œ/, /ɛ/) and nasalized vowels (/ɛ/, /ɔ/, /ɔ/). These vowels differed substantially from any English vowel but were similar to vowels in French.

Level of Analysis

Perception research suggests that speech sounds are processed at three successive levels: auditory, phonetic, and phonemic (see Elman, Diehl, & Buchwald, 1977; Repp, 1981; Pisoni, Aslin, Perey, & Hennessey, 1982; Werker & Logan, 1985; Werker, Klein, & Logan, 1986; Mann, 1986). It is uncertain at which level(s) interlingual identification occurs. Bilinguals judge interlingual distances by comparing incoming L2 phones to perceptual prototypes in long-term memory (Best, McRoberts, & Sithole, 1988; Flege, 1984, 1988a, 1988b). The orthographic classification technique employed in the present study probably favoured the use of phonemic representations (Mann, 1986), but it was also possible that the subjects would be influenced by representations at other processing levels.

Catford (1968) stated that the basis for interlingual identification is "substantial rather than formal" (p. 164). This implies that the L1 prototype against which L2 phones are gauged may be phonetic in nature (Brière, 1966), not phonemic, as usually supposed (e.g. Trubetzkoy 1939; Scholes, 1968a, 1968b; Best et al., 1988). The distinction between phonetic and phonemic levels can be illustrated with reference to Spanish /e/, a vowel phoneme with two allophones. Spanish /e/ is realized as an [ɛ]-quality vowel.

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4 Bilinguals might assess the distance between L1 and L2 sounds by implicitly comparing the gestures needed to produce them (see Scholes, 1968b), but there is as yet no evidence for this.

7 The allophones of Spanish /e/ are in complementary distribution—that is, they occur in mutually exclusive phonetic contexts. Because of this, [e] and [ɛ] cannot be used to contrast meaning in Spanish.
in most closed syllables. These variants are said to "match" the vowel in English "bet" (Dalbor, 1980), a claim supported by a recent L2 vowel intelligibility study (Flege, 1990). As suggested by the symbol used to represent it, Spanish /e/ may be implemented as [e] in other contexts (most open syllables except those preceding /r/, and in closed syllables ending in /s/ or /z/). American English /e/, on the other hand, is implemented with a single allophone (viz. [e']).

Spanish /e/ shows some formant movement, but not nearly as much as the diphthongal English /e/ (Flege, Munro, & Fox, in preparation). In a study using glossometry, Flege (1989a) found that the average tongue position used for the [e] allophone of Spanish /e/ was intermediate between the tongue positions observed in the "onglide" and "offglide" of English /e/. It is uncertain whether bilinguals will identify a diphthongal L2 vowel with a monophthongal L1 vowel. It is also uncertain how they will deal with differing distributions of allophones for phonemes in their two languages. If interlingual identification occurs at a phonemic level, then Spanish speakers of English should consistently identify the realizations of English /e/ in terms of the Spanish /e/ phoneme. The error data in Table 1 indirectly supports this view.

There is reason to suppose, however, that interlingual identification does not occur exclusively at an abstract, phonemic level. If Spanish speakers compare English vowels to the Spanish /e/ phoneme, then their judgements should be influenced by the properties of both the [e] and [e] allophones of that phoneme. A recent study by Flege et al. (in preparation) suggests that this does not happen, at least not in certain tasks. Spanish and English subjects used a 9-point scale to rate pairs of CV syllables for degree of dissimilarity. Some pairs contained realizations of English /æ/ and /e/. Had the Spanish subjects based their judgements on a phonemic representation, they should have judged the [æ]-[e] pairs to be more dissimilar than the English subjects because, for them, [e] phones would be associated via phonemic representations with [æ] phones. However, the Spanish subjects judged the [æ]-[e] pairs to be less dissimilar than did the native English subjects (3.1 vs. 4.2, p = 0.003).

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1 In that study, Spanish speakers produced English "beat", "bit", "bet", and "bat". Their [æ] attempts were identified correctly by native English listeners in most instances, but not their attempts at English /i/, /e/, and /æ/. It remains to be seen whether Spanish learners of English will be successful in producing /æ/ in phonetic contexts in which the [e] allophone of Spanish /e/ would be expected, for example in words like "Bess", "mess", "says".

2 The quality of this vowel varies, of course—for example, the offglide of /æ/ may not be reached at a fast speaking rate.

3 This same kind of reasoning can be applied to CV pairs containing realizations of English /æ/ and Spanish /e/. If subjects used phonemic-level representations exclusively for such pairs, one would expect less perceived dissimilarity for Spanish than English subjects because the [æ]
Changes in Interlingual Identification

In addition to unresolved questions pertaining to the processing level(s) at which interlingual identification occurs, it is uncertain whether patterns of interlingual identification will change as L2 learners grow familiar with the L2 sound system. A change in interlingual identification may be more likely for certain L2 sounds than others.

Some L2 sounds are virtually identical to those in the L1 (Bohn & Flege, submitted), but most differ from any L1 sound, if only in the details of timing, amplitude, or placement of articulatory constrictions. It was once believed that cross-language differences were the primary source of speech learning difficulty (e.g. Stockwell & Bowen, 1965; Brière, 1968). This leads one to expect that L2 sounds that match an L1 sound closely will be produced authentically whereas those that do not match an L1 sound closely will be produced poorly. It may be, however, that a "U"-shaped rather than a linear function best describes the effect of varying differences between L1 and L2 sounds. That is L2 sounds that match an L1 sound closely, or else differ considerably from any sound in the L1 may be produced authentically, whereas L2 sounds that partially resemble an L1 sound may be pronounced poorly.

I have hypothesized that "new" L2 sounds will stop being identified with L1 sounds at some point in L2 learning, whereas "similar" L2 sounds will continue being identified with an L1 sound (Flege, 1988b; 1990; in press, a, b; see also Oller & Ziahoosseiny, 1970; Wode, 1977, 1978). As a result, adult learners may be able to establish phonetic categories for new L2 sounds and eventually produce them authentically. Similar L2 sounds may prove to be the most difficult kind of sound for adult learners because, by hypothesis, they continue to be identified with L1 sounds (which blocks the phonetic category formation needed for authentic production). In support of this, several studies have shown that vowels not found in the L1 inventory are produced more authentically than are L2 vowels that differ acoustically from a counterpart in the L1 (Mueller & Niedzielski 1963; Flege, 1987b; Major, allophone of Spanish /e/ is said to match English /e/ realizations. Instead, the Spanish listeners rated [e]-[e] pairs as more dissimilar than English listeners (4.8 vs. 3.9, p = 0.011). One other recent study points to the operation of phonetic-level processes. In a study by Flege (submitted), Spanish and English subjects estimated degree of rhyme in English words. Both groups rated pairs of English words with /e/ and /e/ (e.g. "mate" vs. "met") to rhyme equally, but they gave different ratings for other word pairs. It was assumed that the Spanish subjects would identify English /e/ with their Spanish /e/, and that vowels classified as being the same "will rhyme more than those classified as different". Had the rhyming judgements been made at a phonemic level, therefore, the Spanish subjects should have perceived a greater degree of rhyme than did the English subjects.
1987; Bohn & Flege, 1990; but cf. Flege, 1990). There is also some preliminary evidence that L2 consonants that are unlike any in the L1 may be produced more authentically than L2 consonants that differ acoustically from an L1 counterpart.\footnote{Best et al. (1988) provided perceptual evidence that Bantu clicks may be sufficiently distinct from any English consonant that they are not identified in terms of an English category. No L2 production study, to my knowledge, has examined click production. Such a study would be problematical, however, because clicks are likely to occur seldom in human languages because they are complex articulatorily. (This would work against the hypothesis that new L2 sounds will be mastered.) Several studies examined the production of English /t/ and /l/ by Japanese speakers. These sounds might be regarded as new, for there is no /t/ in Japanese and the Japanese /l/ is realized as a voiced tip-alveolar flap (see Flege, 1988b, for a review). Speech production and perception research has suggested that at least some native speakers of Japanese can master the /t/-/l/ contrast of English (MacKain et al., 1981; Mochizuki, 1981; Sheldon & Strange, 1982; see also Flege, 1988b). Research examining similar L2 stops, on the other hand, indicate that they will seldom if ever be mastered by adult learners (Flege, 1991).}

Figure 1 shows the distribution of formant values for six English vowels (/i, y, e, æ, a, u/) spoken by 30 male native speakers of American English (Peterson & Barney, 1952) and the five Spanish vowels spoken by 16 native Spanish males (Godinez, 1978). In agreement with articulatory data (Flege, 1989a), English /i/ and /y/ are lower in the \( F_1 - F_2 \) space than Spanish /i/ and /u/, and English /æ/ is posterior to Spanish /a/. The data in Figure 1 largely agree with a study of Argentine Spanish (Guirao & de Manrique, 1972, 1975), which showed that the distribution for Spanish /i/ fell within the ellipse for American English /i/ (Peterson & Barney, 1952). Data reported by Skelton (1969; see also Quiles, 1981; Navarro Tomas, 1980) suggest that this would not be true if the relatively open allophone of /æ/ in closed syllables had been included. The data in Figure 1 agree with the Argentine Spanish data in showing that realizations of /e/ fell entirely within the space occupied by American English /e/ (see also Papçun, 1976; Ladefoged, 1975). The Argentine data for /e/ and that shown in Figure 1 may be misleading, however, because only the [e] allophone of /e/ was examined. Had [e] allophone tokens been included, the Spanish /e/ ellipse in Figure 1 would probably have encompassed much of the \( F_1 - F_2 \) space occupied by English /e/ (see Skelton, 1969).

If interlingual identification were based on proximity in a psychological space resembling the \( F_1 - F_2 \) space in Figure 1, we might expect the following:

1. English /i/ will be identified with Spanish /i/;
2. English /y/ will be identified with Spanish /æ/, /i/;
3. English /æ/ will be identified with Spanish /æ/;
4. English /e/ will not be identified consistently with a Spanish vowel.

\footnote{Best et al. (1988) provided perceptual evidence that Bantu clicks may be sufficiently distinct from any English consonant that they are not identified in terms of an English category. No L2 production study, to my knowledge, has examined click production. Such a study would be problematical, however, because clicks are likely to occur seldom in human languages because they are complex articulatorily. (This would work against the hypothesis that new L2 sounds will be mastered.) Several studies examined the production of English /t/ and /l/ by Japanese speakers. These sounds might be regarded as new, for there is no /t/ in Japanese and the Japanese /l/ is realized as a voiced tip-alveolar flap (see Flege, 1988b, for a review). Speech production and perception research has suggested that at least some native speakers of Japanese can master the /t/-/l/ contrast of English (MacKain et al., 1981; Mochizuki, 1981; Sheldon & Strange, 1982; see also Flege, 1988b). Research examining similar L2 stops, on the other hand, indicate that they will seldom if ever be mastered by adult learners (Flege, 1991).}
FIG. 1. Formant frequency values for six English vowels (/i/, /u/, /e/, /æ/, /ɑ/, /u/) spoken by 30 male native speakers of American and English (Peterson & Barney, 1952) and five Spanish vowels (/i/, /e/, /a/, /o/, /u/) spoken by 16 male native speakers of Spanish (Godinez, 1978), in mels. The ellipses define 95% confidence limits; they are based on the two principle components of variation in F₁ and F₂ values.

Prediction (1) agrees with results obtained in a cross-language perceptual study by Scholes (1967), summarized in Table 2. In that study, English and Spanish subjects used keywords from their L1, or the label “none”, to identify a matrix of 69 isolated synthetic vowels in which F₁ and F₂ frequencies were varied. The vowels typically heard as /i/ by native English subjects were also heard as /i/ by the Spanish subjects. In agreement with the error analyses in Table 1, but in apparent disagreement with Prediction (2) above, /i/-quality vowels were always heard as /i/ by Scholes’ Spanish subjects, never as /e/. Prediction (3), as stated, would be true only if interlingual judgements are made exclusively at a phonemic level. The finding that /e/-quality vowels were sometimes identified as “none” by

\[\text{One reason for caution in regards to Scholes’ (1967) /i/ data is that just one of the 69 synthetic vowel stimuli was heard consistently by English subjects as /i/, probably because the stimuli were 400 msec long.}\]
**TABLE 2**

Tabulation of Perceptual Data Reported by Scholes (1967).

Labelling by native Spanish listeners of vowels typically classified as \(/i, /e, /a, /o u, /o, /u\) by native speakers of English

<table>
<thead>
<tr>
<th>Sounds Typically Classified by English Subjects</th>
<th>Heard by Spanish Subjects</th>
<th>Sound</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>(/i)</td>
<td>(/i)</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>(/i)</td>
<td>(/i)</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>(/e)</td>
<td>(/e)</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>(/e)</td>
<td>(/e)</td>
<td></td>
<td>72</td>
</tr>
<tr>
<td>(/e)</td>
<td>none</td>
<td></td>
<td>28</td>
</tr>
<tr>
<td>(/e)</td>
<td>none</td>
<td></td>
<td>89</td>
</tr>
<tr>
<td>(/e)</td>
<td>(/e)</td>
<td></td>
<td>11</td>
</tr>
<tr>
<td>(/a)</td>
<td>(/a)–100%</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>(/o u)</td>
<td>(/o)–100%</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>(/u)</td>
<td>(/u)</td>
<td></td>
<td>60</td>
</tr>
<tr>
<td>(/u)</td>
<td>none</td>
<td></td>
<td>40</td>
</tr>
</tbody>
</table>

Labelling by native English listeners of vowels typically classified as \(/i, /e, /a, /o, /u\) by native Spanish speakers

<table>
<thead>
<tr>
<th>Sounds Typically Classified by Spanish Subjects</th>
<th>Heard by English Subjects</th>
<th>Sound</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>(/i)</td>
<td>(/i)</td>
<td></td>
<td>70</td>
</tr>
<tr>
<td>(/i)</td>
<td>(/i)</td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>(/e)</td>
<td>(/e)</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>(/e)</td>
<td>(/e)</td>
<td></td>
<td>41</td>
</tr>
<tr>
<td>(/e)</td>
<td>(/e)</td>
<td></td>
<td>29</td>
</tr>
<tr>
<td>(/e)</td>
<td>(/e)</td>
<td></td>
<td>18</td>
</tr>
<tr>
<td>(/e)</td>
<td>none</td>
<td></td>
<td>12</td>
</tr>
<tr>
<td>(/a)</td>
<td>(/a)</td>
<td></td>
<td>88</td>
</tr>
<tr>
<td>(/a)</td>
<td>(/a)</td>
<td></td>
<td>12</td>
</tr>
<tr>
<td>(/o)</td>
<td>(/o)</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>(/o)</td>
<td>none</td>
<td></td>
<td>33</td>
</tr>
<tr>
<td>(/o)</td>
<td>(/o)</td>
<td></td>
<td>17</td>
</tr>
<tr>
<td>(/u)</td>
<td>(/u)</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>(/u)</td>
<td>(/u)</td>
<td></td>
<td>50</td>
</tr>
</tbody>
</table>
Scholes’ Spanish subjects suggested that their judgements were based, at least in part, on phonetic-level representations. Perhaps the most interesting observation to be drawn from Scholes’ (1967) data is that the Spanish subjects seemed to use the “none” response predominantly to label [æ]-quality vowels. This agrees with the acoustic data in Figure 1 and is consistent with the observation that Spanish speakers of English mispronounce English /æ/ in a variety of ways (Table 1). This may mean that /æ/ emerges as a new vowel for native Spanish learners of English. Such a conclusion is by no means certain, however, because Scholes made use of isolated synthetic vowels. The subjects might have used the “none” response because some incidental property of the stimuli (e.g. duration) diverged from values specified in their central representation of the closest Spanish vowel.

Decisions as to whether a vowel is “different” from any L1 vowel may be influenced by response biases and perhaps subtle aspects of experimental design, such as the wording of instructions. The criterion used here to determine whether an English vowel emerges as “new” was the pattern of behaviour observed for groups of native Spanish subjects differing in English-language experience. Experiment 1 examined Spanish subjects who had little or no prior exposure to English (i.e. Spanish monolinguals). Experiments 2 and 3 examined Spanish speakers of English who differed in L2 experience. Experiment 3 differed from the first two experiments in using instructions that encouraged subjects to use the “none” label. If English /æ/ emerges as a new vowel, we would expect Spanish speakers of English to use the “none” label for /æ/ more often than Spanish monolinguals but not to differ from the monolinguals in the frequency with which “none” is applied to other English vowels. If L2 learners recognize only gradually that certain L2 vowels are new, we might see no difference between inexperienced Spanish speakers of English and Spanish monolinguals, but observe the kind of difference just described between relatively experienced and inexperienced Spanish speakers of English.

EXPERIMENT 1

Method

Ten native speakers of English (5 males, 5 females) living in Birmingham, Alabama, read a randomized list containing multiple repetitions of English “beat”, “bit”, “bet”, and “bat”. The first three repetitions of each word were

This is especially true given that the Spanish subjects were offered two Spanish keywords with which to label the synthetic vowels—one that contained the [æ] allophone (viz. ser) and one with the [e] allophone (viz. de).
lowpass-filtered at 4.8 kHz and digitized at 10 kHz with 12-bit amplitude resolution. The formant frequencies of all 120 words (10 talkers × 4 vowels × 3 repetitions) were estimated using LPC analysis (14 coefficients for males, 12 for females) by placing a 25.6-msec Hamming window at the acoustic midpoint. Fundamental frequency (F0) measurements were based on the duration of three successive glottal periods at the vowel midpoint. “Vowel” duration was measured (in msec) from the onset to the offset of periodicity in each waveform.

Table 3 presents the mean acoustic values for the five female talkers who produced the English /bVt/ words used as stimuli in Experiments 1–3. Table 4 presents the mean values for the five male talkers. As expected, /i/ was longer than /i/, and /æ/ was longer than /e/. Also as expected, F0 was slightly higher for the two high vowels (/i/, /i/) than for the two non-high vowels (/e/, /æ/). For the most part, the formant frequency values reported in Tables 3 and 4 correspond to values published for American English by Peterson and Barney (1952).

In Figure 2 the 15 tokens of each vowel obtained from the male talkers are plotted in an F1–F2 space along with ellipses defining native Spanish males’ productions of the Spanish vowels /i/, /e/, /a/, /o/, and /u/ (Godinez, 1978). All but one English /i/ token fell within the ellipse for Spanish /i/. Most of the English /i/ tokens fell within the Spanish /e/ ellipse. One English /e/ token fell within the /e/ ellipse, but most fell outside any Spanish ellipse (usually closer to Spanish /e/ than /a/). None of the English /æ/ tokens fell within a Spanish vowel ellipse, but most were slightly closer to Spanish /a/ than /e/.

The 120 English /bVt/ words were normalized for peak intensity, then recorded on audio tape (Marantz PMD 420) for later playback to subjects. Two randomizations of the 12 words spoken by each talker (4 words × 3 repetitions) were recorded. The five male talkers were recorded on Side A of the tape, the five females on Side B. The interval between each word was fixed at 2.5 sec. The interval between talkers was 10 sec. Sides A and B were presented binaurally over headphones in a sound-booth to 20 monolingual speakers of Spanish. The paid subjects (11 males, 9 females) had a mean age of 27 years (S.D. = 9). Each reported having normal hearing. Most subjects had been in the United States for only several weeks at the time of testing. Fourteen were from Mexico, five were from El Salvador, and one was from Argentina. It is not known what influence, if any, the variations in native dialect of Spanish may have had on the results.

A native Spanish research assistant read instructions in Spanish to the subjects. They were told to identify the vowel in each word by circling <i>, <e>, <a>, <o>, or <u> on a specially prepared answer sheet, or by circling “ninguno” (none) if they heard a vowel “not found in Spanish”. The subjects were told to guess if they were uncertain. The words spoken by one talker (24 stimuli) were presented for practice before the experiment began.
Half of the subjects heard a male talker on Side A for practise, the other half a female talker on Side B. This may have been insufficient in a few instances. A total 5.5% of the data, all from three subjects, had to be discarded because of missing responses.  

Each listener marked 24 answers in response to the vowels of the 10 talkers, as required, but the three listeners just mentioned probably did not respond to every word as it was presented.
in the few blocks. It appears that these listeners missed a response but attempted to conceal this fact by marking an answer(s) at the end of the answer sheet after the last word had been presented, resulting in responses that were out of sequence with the stimuli. All data obtained in response to a particular talker were discarded if two or more obviously inappropriate responses were obtained for that talker. "Inappropriate" was defined here as an <a> response for either "beat" (/bit/) or "bit" (/bil/). It seems highly unlikely that such a response could be anything other than a mistake.

---

**TABLE 4**

Duration* and Frequency* in the Vowels Found in "Beat", "Bit", "Bet", and "Bat" as Spoken by Five Adult Male Native Speakers of American English

<table>
<thead>
<tr>
<th>Vowel</th>
<th>Talker</th>
<th>Dur.</th>
<th>F0</th>
<th>F1</th>
<th>F2</th>
<th>F3</th>
</tr>
</thead>
<tbody>
<tr>
<td>/i/</td>
<td>1</td>
<td>131</td>
<td>111</td>
<td>263</td>
<td>2523</td>
<td>3171</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>164</td>
<td>115</td>
<td>322</td>
<td>2486</td>
<td>2989</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>202</td>
<td>104</td>
<td>312</td>
<td>2044</td>
<td>2764</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>195</td>
<td>84</td>
<td>319</td>
<td>2512</td>
<td>2876</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>234</td>
<td>129</td>
<td>279</td>
<td>2260</td>
<td>3007</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>185</td>
<td>109</td>
<td>299</td>
<td>2365</td>
<td>2962</td>
</tr>
<tr>
<td>/u/</td>
<td>1</td>
<td>108</td>
<td>102</td>
<td>436</td>
<td>1929</td>
<td>2739</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>120</td>
<td>111</td>
<td>458</td>
<td>1993</td>
<td>2746</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>158</td>
<td>117</td>
<td>461</td>
<td>1555</td>
<td>2451</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>146</td>
<td>80</td>
<td>471</td>
<td>1768</td>
<td>2695</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>225</td>
<td>125</td>
<td>389</td>
<td>1933</td>
<td>2648</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>151</td>
<td>107</td>
<td>443</td>
<td>1835</td>
<td>2656</td>
</tr>
<tr>
<td>/e/</td>
<td>1</td>
<td>116</td>
<td>93</td>
<td>621</td>
<td>1821</td>
<td>2643</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>161</td>
<td>110</td>
<td>590</td>
<td>1837</td>
<td>2709</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>214</td>
<td>105</td>
<td>549</td>
<td>1430</td>
<td>2288</td>
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<tr>
<td></td>
<td>4</td>
<td>160</td>
<td>80</td>
<td>536</td>
<td>1758</td>
<td>2694</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>247</td>
<td>119</td>
<td>475</td>
<td>1825</td>
<td>2579</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>180</td>
<td>101</td>
<td>554</td>
<td>1734</td>
<td>2582</td>
</tr>
<tr>
<td>/æ/</td>
<td>1</td>
<td>182</td>
<td>98</td>
<td>711</td>
<td>1926</td>
<td>2604</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>175</td>
<td>98</td>
<td>766</td>
<td>1683</td>
<td>2615</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>273</td>
<td>103</td>
<td>697</td>
<td>1530</td>
<td>2219</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>223</td>
<td>81</td>
<td>701</td>
<td>1739</td>
<td>2549</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>300</td>
<td>110</td>
<td>661</td>
<td>1840</td>
<td>2738</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>231</td>
<td>98</td>
<td>707</td>
<td>1744</td>
<td>2545</td>
</tr>
</tbody>
</table>

* Duration in msec.
* Frequency in Hz.

**Note:** Each talker mean is based on three tokens.
The frequency with which <i>, <e>, <a>, <o>, <u>, and “none” were used by each subject to label the four English vowels was computed. For all but the three subjects just mentioned, the frequencies for each vowel were based on 60 responses (10 native English talkers × 3 replicate tokens × 2 randomizations). T-tests were performed to determine whether a particular response was used to label each vowel at a rate significantly exceeding zero. Since 24 t-tests were performed (4 vowels × 6 possible response labels), an alpha level of 0.004 was used to give an experiment-wise error rate of 0.10 (Snedecor & Cochran, 1980).

Results and Discussion

Figure 3 shows the mean frequency with which <i>, <e>, <a>, <o>, <u>, or “none” was used to label the English vowels. An asterisk in this figure and those to follow indicates that a response label was used at a significantly above-chance rate (p < 0.10). The Spanish subjects' most frequent response for both English /i/ and /I/ vowels was <i> (94%, 68%),
suggesting that they identified both English vowels in terms of the Spanish /i/ phoneme. The subjects also gave a few <e> and "none" responses for /i/ (19%, 12%), but not at above-chance rates. The most frequent response for English /e/ was <e> (81%). The subjects also used <a> to label English /e/ in a small (13%) but significant number of instances. The most frequent response for /æ/ was <a> (71%), but <e> was also used at an above-chance rate (17%).

The results for /i/ and /e/ agree with the acoustic and perceptual results presented in the Introduction. The results for /i/ agree better with Scholes' (1967) perceptual data than an inference drawn from acoustic data, viz. that /i/ would be identified frequently with Spanish /e/. Perhaps the relatively short duration of the English /i/, or its centring offglide (Flege et al., in preparation), distinguished it from Spanish /e/. The most surprising result was the one obtained for /æ/. Previously published acoustic data showed that this English vowel is about midway between Spanish /e/ and /a/ in an F₁-F₂ space (Figure 1)—that is, /æ/ does not seem to occupy a portion of the acoustic vowel space exploited by a Spanish vowel. The particular /æ/ tokens used here (at least the males') fell outside any Spanish vowel ellipse. They were only slightly closer, perhaps, to the Spanish /a/ than /æ/. This, taken together with the finding that the Spanish subjects in Scholes' (1967) study often applied the "none" label to [æ]-quality vowels, suggests that Spanish
monolinguals would not identify English /æ/ in terms of a Spanish vowel category.

The Spanish monolingual subjects nevertheless identified /æ/ consistently with the Spanish /a/. Thus the labelling data obtained in this experiment suggest that Spanish learners of English do not treat English /æ/ as new. This conclusion is consistent with the results of a recent intelligibility study. Flege (1990) found that Spanish speakers' attempts at /æ/ in the word *bat* were identified by American English listeners as */a* or */a/ in over one-fourth of instances. This relatively high frequency of misperception does not prove that Spanish learners fail to establish a category for /æ/, but it is at least consistent with that interpretation.

EXPERIMENT 2

Experiment 2 further explored the extent to which Spanish speakers of English will note a difference between English /i/, /e/, /æ/, /u/ and vowels found in their L1. More specifically, the purpose of Experiment 2 was to determine whether native Spanish speakers of English would use the “none” label significantly more often than the monolingual subjects in Experiment 1, and significantly more often for /æ/ than for the other three English vowels examined.

Method

The stimuli from Experiment 1 were presented to 20 native Spanish speakers of English living in Birmingham, Alabama. The mean age of the subjects (10 male, 10 female) was 29 years (S.D. = 6). They had arrived in the United States at an average age of 25 years (S.D. = 6) and estimated using English about 65% of the time on a daily basis (S.D. = 19). The subjects differed considerably in terms of L2 experience. Length of residence in the United States ranged from 4 months to 10 years (M = 5 years, S.D. = 5). Ten “inexperienced” subjects had lived in the United States for only 0.8 years, on the average, and 10 “experienced” subjects had lived in the United States for 6.8 years. A total of 4% of the data was declared missing (see Footnote 14). The frequency with which the six response categories (<i>, <e>, <a>, <o>, <u>, “none”) were used to label the four English vowels was calculated as before.

Results and Discussion

A series of Mann-Whitney tests were carried out on the frequency data to determine whether the 10 experienced and the 10 inexperienced subjects responded differently. In many instances a response label was not used at all, or only marginally. Tests were carried out only if a label was used in at least 5% of instances overall. This criterion was met in 12 instances. A 0.004 alpha
level was used for the 12 tests to give an experiment-wise error rate of 0.05 (Snedecor & Cochran, 1980).

No difference between the experienced and inexperienced speakers of English was significant. Only two between-group differences approached significance. The experienced subjects gave more <e> responses to /ɛ/ than did the inexperienced subjects (57% vs. 31%); conversely, they gave fewer <a> responses to /ə/ than did the inexperienced subjects (26% vs. 53%) \([U=21.5, p=0.028; U=18.0, p=0.015]\). These tendencies suggest that Spanish subjects who are relatively inexperienced in English may have difficulty in relating English /ɛ/ to the [ɛ] allophone of Spanish /e/ if it occurs in an unfamiliar phonetic context (i.e. preceding a word-final stop).

The responses obtained for the experienced and inexperienced speakers of English have been combined in Figure 4 because none of the between-group differences was statistically significant. English /i/ was labelled as <i> in 84% of instances. English /i/ received the following responses at above-chance rates: <e> (39%), <i> (36%), and “none” (21%). An inference drawn from acoustic analyses of Spanish and English vowels in the Introduction was that English /i/ might be identified more closely with Spanish /e/ than with Spanish /i/. The response pattern obtained here in Experiment 2 is more consistent with this inference than is the response pattern obtained in

![Figure 4](image-url)

**FIG. 4.** The mean percentage of instances in which the Spanish speakers of English in Experiment 2 used <i>, <e>, <a>, <o>, <u>, and “none” as labels for the vowels in “beat”, “bit”, “bet”, and “bat” (/i/, /l/, /e/, /æ/). Data for experienced and inexperienced native Spanish speakers of English have been pooled because these subgroups did not differ significantly. Frequencies that significantly exceeded zero are marked by an asterisk; the error bars enclose ± 1 S.E.
Experiment 1. Thus, the Experiment 2 data for /i/ suggest indirectly that Spanish speakers of English may be better able to appraise the phonetic characteristics of English vowels than subjects without such familiarity. Three responses were obtained at above-chance rates for English /e/: <e> (44%), <a> (39%), and "none" (13%). One might expect English /e/ to be identified with Spanish /e/ because this phoneme has an [e] allophone. "None" responses might be expected because the /e/ realizations in "bet" occurred in an unaccustomed phonetic context (i.e., preceding a word-final stop). The only explanation that comes to mind for why English /e/ was sometimes labelled <a> is the acoustic similarity of some of the English /e/ realizations to Spanish /a/ (see Figure 2). Two responses at above-chance rates were obtained for English /æ/: <a> (82%) and "none" (12%). This finding does not support a conclusion that might be drawn from Scholes' (1967) perceptual study, viz. that Spanish speakers judge English /æ/ to be a new vowel.

"None" responses were obtained more often from bilinguals in the present experiment than from the monolingual subjects in Experiment 1. The frequencies of none responses obtained in Experiments 1 and 2 were: /i/ (0% vs. 8%), /ι/ (12% vs. 21%), /e/ (1% vs. 13%), and /æ/ (10% vs. 12%). The differences between experiments were all significant at the 0.05 level [U=107.0, 119.0, 65.0, 118.0]. The same procedures were used for the bilinguals and monolinguals, so these results suggest that the Spanish speakers of English had begun to note some of the acoustic differences between English and Spanish vowels. However, although the Spanish/English bilinguals used the "none" label more often than did the Spanish monolinguals, a few bilinguals used it as their predominant response for the English vowels. The rate of "none" never exceeded an average 20% for any vowel in Experiment 2; and only 12 of the 20 individual subjects used "none" in more than 10% of instances in responding to the four vowels. If we consider all 40 subjects who participated in Experiments 1 and 2, the rate of "none" responses exceeded 50% in only 10 of the 160 possible instances (40 subjects × 4 vowels). Six subjects used "none" as their predominant label for /i/; and four used it predominantly for /æ/ (see Figure 7 below).

Of the four American English vowels examined, /i/ and /æ/ are probably the least like a Spanish vowel phoneme in acoustic phonetic terms. We reexamined the data obtained for those subjects from Experiments 1 and 2 who were not reluctant to use the "none" response. The "non-reluctant" subjects were defined as all those who responded "none" in more than 10% of instances overall. The frequencies with which the "none" response was used in labelling /i/ and /æ/ by these 18 subjects were compared to the frequencies for /ι/ and /e/. The combined frequency of "none" response for the non-reluctant subjects was significantly greater for /i/-/æ/ than /i/-/e/ (28% vs. 13%) [H=12.1, df=3, p=0.007]. Still, had the Spanish subjects established phonetic categories for English /i/ and /æ/, we would have
expected “none” responses to be used more consistently. Thus the results obtained in the first two experiments do not strongly support the hypothesis that any of the English vowels examined here will be treated as “new” by adult Spanish learners of English.

EXPERIMENT 3

The inter-subject variation in the use of “none” suggests that it may be difficult to determine, in an absolute sense, whether bilinguals judge an English vowel to be phonetically or phonemically distinct from vowels in the L1 inventory. The orthographic classification of L2 vowels in Experiments 1 and 2 resembles an experiment described recently by Johnson (1990), where subjects were asked to determine whether words synthesized with different F0 values had been spoken by the same talker or by different talkers. One listener identified only those words produced with an identical F0 values as having been produced by the same talker. Other listeners had a more liberal standard. Some, in fact, seemed willing to attribute any detectable F0 difference to a difference in speaker identity.

It is possible that some subjects in the Experiments 1 and 2 were more willing to use the “none” label than other subjects as the result of a general response bias. If so, it should be possible to manipulate the frequency of “none” responses. We attempted to do so in Experiment 3 by using instructions that were quite different from those used in the two earlier experiments. The new instructions encouraged subjects to use the “none” label. Under the new instructions, “none” might be used often enough to warrant concluding that an English vowel emerges as “new” for Spanish speakers of English.

Method

The stimuli used in Experiments 1 and 2 were again used here. The only important change in procedures was in the instructions read in Spanish to the subjects. The subjects in Experiments 1 and 2 were told that the purpose of those experiments was to “compare” Spanish and English vowels. Here, they were told that the purpose of the experiment was to identify differences between Spanish and English vowels. The Experiment 1 and 2 subjects were told to circle one of five vowel letters, but to use “none” if they did not hear a vowel from Spanish. Included in the instructions for Experiment 3 was the observation that “many English vowels are unlike any vowel in Spanish”. The subjects were told to use “none” if they heard one of these “different” English vowels, but to use one of the five letters if they thought they had heard a Spanish vowel.

Twenty additional native Spanish speakers of English were drawn from the same population as in Experiment 2. The average age of the subjects (10
male, 10 females) was 28 years ($S.D. = 6$). These subjects had arrived in the United States at an average age of 25 years ($S.D. = 7$), had studied English for an average of 5 years ($S.D. = 5$), and estimated that they used English about 56% of the time on a daily basis ($S.D. = 31$). A subgroup of ten inexperienced subjects had lived in the United States for only 0.4 years on the average at the time of the study; 10 relatively experienced subjects had lived in the United States for an average of 6.4 years.

Results and Discussion

A series of Mann-Whitney tests was carried out to test for between-group differences. Tests were not carried out when a label was used in less than 5% of instances. The alpha level was set at 0.0045 for the 11 tests that were performed to ensure an experiment-wise error rate of 0.05. No between-group difference reached significance. The largest difference observed was for the “none” response as applied to /l/. The experienced subjects used “none” more often than did the inexperienced subjects (51% vs. 25%) ($U = 23.0$, $p = 0.043$). A non-significant trend in the opposite direction was observed for “none” responses to /æ/ (13% vs. 23%) ($U = 49.0$, $p = 0.971$).

The data for the experienced and inexperienced subjects have been combined in Figure 5 because the differences between the two subgroups were non-significant. The “none” response was used more often here than in

![Figure 5](image-url)

FIG. 5. The mean percentage of instances in which the Spanish speakers of English in Experiment 3, where instructions encouraged “none” responses, used <i>, <e>, <a>, <o>, <u>, and “none” to label the vowels in “beat”, “bit”, “bet”, and “bat”. Data for experienced and inexperienced speakers of English have been pooled because these subgroups did not differ significantly. An asterisk indicates above-chance frequencies; the error bars enclose ±1 S.E.
Experiment 2 (23% vs. 14%), but the difference was smaller than expected, given the major change in instructions (see above). Mann–Whitney tests were used to test for differences in the frequency of “none” responses in Experiments 2 and 3. The difference between Experiment 2 and Experiment 3 was non-significant for /i/ (8% vs. 9%) and for /æ/ (12% vs. 18%) [U = 190.0, 180.0]. The difference for /i/ (21% vs. 38%) was marginally significant, $U = 133.5, p = 0.072$; the difference for /æ/ (13% vs. 27%) reached significance at the 0.05 level, $U = 111.5, p = 0.016$. Recall that the Spanish speakers of English in Experiment 2 used “none” more often than did the Spanish monolinguals in Experiment 1 (14% vs. 6% overall). It thus appears that manipulating instructions had about as much influence on subjects’ likelihood to use “none” for an English vowel as did learning to speak English.

The subjects in Experiment 3 used <i> to label the English /i/ realizations in most instances (88%). For /i/, three responses were used at above-chance rates: <i> (39%), none (38%), and <e> (23%). Taken together with the results of Experiment 2, this suggests that Scholes’ (1967) 400-msec synthetic stimuli probably did not permit an accurate assessment of how Spanish speakers identify English /i/. Apparently, the acoustic overlap between English /i/ and Spanish /æ/ realizations is sufficient to cause at least some Spanish/English bilinguals to identify the two vowels with one another perceptually.

Three responses were obtained at above-chance rates for English /æ/: <e> (48%), none (27%), and <a> (22%). Taken together with the results of Experiment 2, this suggests that both phonetic and phonemic-level processing influenced the subjects’ labelling. Had labelling been based entirely on phonemic-level decisions, one would have expected the subjects to use the <e> response consistently. Apparently, they were influenced by the acoustic–phonetic similarity of certain English [æ] realizations to Spanish /a/ (see Figure 2), and perhaps also by the fact that the English [æ] realizations occurred in an unfamiliar phonetic context. Two responses were obtained at above-chance rates for /æ/: <a> (82%) and “none” (18%). Taken together with the results of Experiment 2, this strongly suggests that, contrary to an inference drawn from Scholes’ (1967) perceptual study, Spanish speakers of English do not regard /æ/ as a new vowel.

**EFFECTS OF ENGLISH-LANGUAGE EXPERIENCE**

We saw little difference in the frequency of “none” responses between relatively experienced and inexperienced Spanish speakers of English in Experiments 2 and 3. The possibility existed that significant effects of L2 experience might be evident if the data from these two experiments were combined. That was the purpose of this section. Characteristics of the 20 experienced and 20 inexperienced subjects from Experiments 2 and 3 are
summarized in Table 5. The experienced subjects had arrived in the United States at an earlier average age than the inexperienced subjects (22.5 vs. 28.1 years) and had lived there longer (6.6 vs. 0.6 years). The two groups were matched fairly closely, however, in terms of chronological age, amount of formal education in English, and self-estimated daily usage of English.

One-half of the experienced Spanish speakers of English received the “neutral” Experiment 2 instructions, whereas the other half received the instructions from Experiment 3, which encouraged the use of “none”. The same proportion of inexperienced and experienced Spanish subjects received the two types of instruction, so it is possible to draw valid comparisons between the two groups. It would not be valid, on the other hand, to compare either group of bilinguals to the 20 Spanish monolinguals, whose characteristics are also summarized in Table 3. This is because all of the monolinguals received the “neutral” instructions. The monolinguals’ results are nevertheless juxtaposed to those of the bilinguals in Figure 6 for the sake of completeness.

Inspection of Figure 6 reveals that the subjects in all three groups used <i> predominantly to label English /i/, and <a> predominantly to label /æ/. There was not a systematic increase in “none” responses for /æ/, suggesting that /æ/ does not emerge as a new vowel. The greatest effects of L2 experience seemed to be for /i/ and /æ/. Use of the <i> label for English /i/ decreased, and use of “none” responses for English /i/ increased, as function of L2 experience. This suggests that /i/ may be treated as a new vowel by at least some experienced Spanish speakers of English.

Compared to the monolinguals, the Spanish speakers of English were more likely to judge the English vowel /æ/ in “bet” as non-Spanish. For some
FIG. 6. Comparison of the results obtained in Experiments 1–3.
reason, the inexperienced subjects who had just begun learning English seemed to identify English /e/ with Spanish /a/ at a relatively high rate. The experienced speakers of Spanish did so at a lower rate, thereby resembling the Spanish monolinguals.

Mann–Whitney tests were carried out to test for differences between the experienced and inexperienced Spanish subjects. The alpha level was set at 0.0045 because a total of 11 tests was performed. (Tests were not carried out in the 13 instances where a label was used in fewer than 5% of instances.) None of the between-group difference reached significance. It is worth noting, however, that the difference in the frequency with which the experienced and inexperienced subjects used “none” in labelling /ɪ/ (42% vs. 18%) came very close to reaching significance \(U = 99.5, p = 0.0056\), as did the between-group difference in \(<a>\) responses for /ɛ/ (21% vs. 40%; \(U = 105.0, p = 0.0095\)).

**GENERAL DISCUSSION**

Spanish monolinguals and Spanish speakers of English who differed in English-language experience used one of the five vowel letters of “none” to classify the American English vowels in “beat”, “bit”, “bet”, “bat” (i.e., /ɪ/, /ɪt/, /ɛ/, and /æ/) Their response patterns were, for the most part, predictable on the basis of the acoustic relationship between Spanish and English vowels as described in the Introduction.

The study yielded several important findings. Changing instructions so as to encourage the use of “none” resulted in a 9% increase in the frequency of “none” responses. The size of the increase was of about the same magnitude as the difference between Spanish monolinguals and Spanish speakers of English who received the same instructions (6% vs. 14%). Apparently, learning English heightens native Spanish speakers’ awareness of acoustic–phonetic differences between Spanish and English vowels. Directing subjects’ attention to cross-language vowel differences via experimental instructions may result in a similar heightened awareness. This will need to be explored further, however, as the observed effect may simply have been due to a change in response bias (i.e. an overall greater propensity to respond “none”).

There was little evidence that Spanish learners of English will judge /æ/ in the context of word-final /ɪ/ to be a “new” (non-Spanish) vowel. Even experienced Spanish speakers of English seem to continue identifying English /æ/ realizations in terms of their Spanish /a/ category. In this sense they differ from native speakers of German, another language that has no /æ/ phoneme. Germans seem to identify English /æ/ with German /e/ or /ɛ:/ (Bohn & Flege, 1990). Native speakers of Mandarin Chinese and Korean also seem to identify English /æ/ with an /ɛ/ (or /ɛ/-like) category in their L1 (Flege, 1990).
Some Spanish subjects in the present study seemed to be aware of the difference between English /t/ and vowels in the Spanish inventory. Inexperienced Spanish speakers of English applied the "none" (i.e., non-Spanish) label to English /t/ more often than did Spanish monolinguals. Also experienced Spanish speakers of English used "none" for /t/ more often than did inexperienced Spanish speakers of English. The difference between the experienced and inexperienced subjects (42% vs. 18%) just missed reaching significance, however (p = 0.0056).

The results obtained here for /t/ and /æ/ provide insight into results obtained in a forced-choice identification experiment by Flege and Bohn (1989). The members of synthetic continua ranging from "beat" to "bit" (/i/-/t/) and "bet" to "bat" (/e/-/æ/) were presented to native speakers of English and to experienced and inexperienced Spanish speakers of English. Only a few Spanish subjects resembled the native English subjects in showing a clear crossover from /i/ to /t/ responses as a function of spectral changes. (Those who did not use spectral changes divided the continuum on the basis of duration differences.) However, nearly all of the Spanish subjects resembled the native English subjects in showing a clear crossover from /e/ to /æ/ responses as a function of spectral changes in the stimuli. The results obtained here suggest that the Spanish subjects tested by Flege and Bohn (1989) probably did not succeed on the /e/-/æ/ continuum as a result of having formed an /æ/ category. They may simply have appeared to resemble native English subjects as a result of identifying the /æ/ endpoint of the synthetic continuum in terms of their Spanish /a/ category. The few Spanish subjects who resembled the native English subjects for the /i/-/t/ continuum, on the other hand, may have succeeded as the result of having formed an /t/ category (unless, of course, they identified the /t/ endpoint with Spanish /e/).

An examination of responses to English /e/ suggested that the orthographic responses may not have been based entirely on phonemic level classifications. Had this been so, we would have expected the <e> label to have been applied consistently to realizations of English /e/. This is because Spanish /e/ has an [e] allophone said to match the English /e/ in "bet" (Dalbor, 1980). However, the subjects often used <a> and "none" responses for English /e/. Of the 20 bilingual subjects in Experiment 2 (where use of the "none" response was not specifically encouraged), four used <e> in more than 75% of instances to identify English /e/, three used <a> in more than 75% of instances, and the remaining 13 used both <e> and <a>. The <a> responses might be attributed to the acoustic phonetic similarity of certain realizations of English /e/ and Spanish /a/ (see Figures 1 and 2). The "none" responses to English /e/ might be attributed to the fact that the English /e/ realizations occurred in a phonetic context in which such vowels are not found in Spanish (i.e. preceding a word-final /t/).

The study did not provide strong support for the hypothesis that certain
English vowels will be treated as "new" by adult native speakers of Spanish. There was, however, a high degree of inter-subject variability in the use of the "none" response, especially for /i/ and /æ/ (in *bit, bat*). Figure 7 shows the frequency with which the "none" label was applied to these vowels by the 60 subjects who participated in Experiments 1-3. It appears that English /æ/ and especially English /i/ fell outside the bounds of the Spanish vowel system for at least some subjects. It has been hypothesized that the authentic production of L2 sounds that are not identical to sounds in the L1 requires the formation of additional phonetic categories, and that L2 phonetic category formation is blocked when interlingual identification persists (Flege, 1988b; 1990; in press, a, b). The possibility therefore exists that the subjects who frequently judged English /æ/ and /i/ to be non-Spanish were better at producing these vowels than were the subjects who seldom used the "none" label. Production was not tested in this study, however. It would be useful to examine production and orthographic classification together in a future experiment.

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