The Perception of English Vowels by Monolingual, Bilingual, and Heritage Speakers of Spanish and English

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1. Introduction

The present study investigates the perception of English vowels by monolingual, bilingual, and heritage English and Spanish speakers. The researcher has as a primary goal the improvement of understanding of second language speech learning, especially as it relates to heritage or early bilingual speakers of the languages in question. This data can be used to better describe how heritage language learning differs from traditional L2 learning. The findings have implications for both language teaching and theoretical models of speech perception. I will begin with a description of the vowel systems of the languages being studied, followed by an overview of speech perception research, and information on the current study.

1.1. Spanish and English Vowel Systems

Most dialects of Spanish have five monophthongs: /i e a o u/. Each of these vowels occurs in both stressed and unstressed syllables (Morgan 2010, Hualde 2005). The mean first and second formant values for Spanish monophthongs are given in Figure 1.1. In addition to monophthongs, Spanish also has several diphthongs which can occur word-internally and across word boundaries: /ai, ia, au, ua, oi, io, ei, ie, eu, ue/ (Hualde & Prieto 2002).

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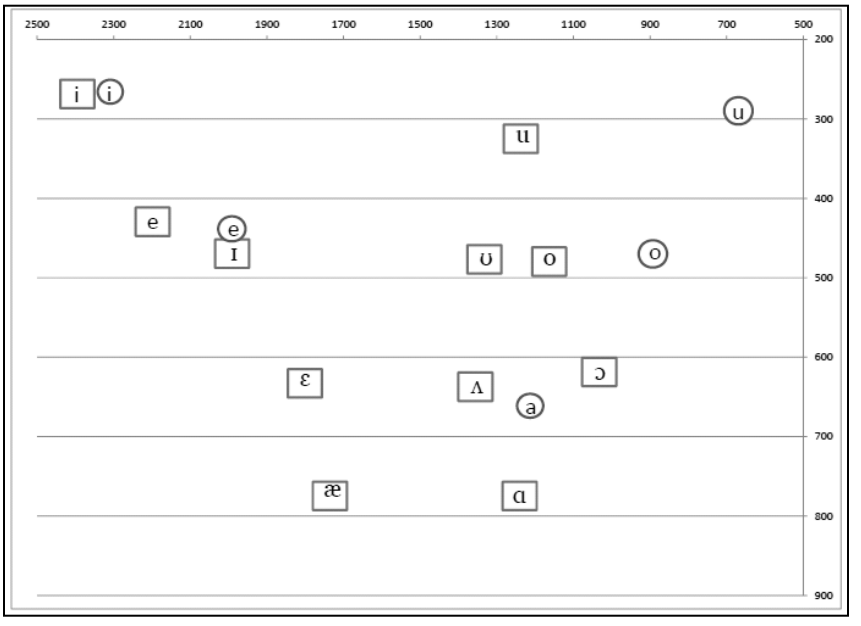

Figure 1.1 Plot of mean F1 and F2 values for Spanish and English vowels. Spanish data (blue circles) taken from Hualde (2005) averaged over 16 male speakers and English data (red squares) taken from Bradlow (1995) averaged over 4 male speakers.

The number of vowels in English varies by dialect, with most speakers of American English having eleven stressed vowel phonemes in their inventory: /i, ɪ, e, ɛ, æ, ɑ, ɔ, o, ʊ, u, ʌ/ (Hualde 2005, Bradlow 1995). Of these, two are traditionally considered to be phonetic diphthongs: /e/ and /o/ (often transcribed as [eɪ] and [oʊ]). The mean first and second formant values for English vowels are given in Figure 1.1 above. English speakers employ duration differences and spectral cues during the production and perception of vowels, as well vowel inherent spectral change or VISC (Morrison, 2006). Spanish speakers learning English must learn to distinguish a larger number of vowels and to make use of duration and spectral cues that are not normally relevant for Spanish vowel perception.

1.2. Speech Perception

The sections that follow are an overview of current native language and cross-linguistics speech perception theories and models. The explanation of these models is brief and primarily includes only information relevant to the current study.

1.2.1. L1 Speech Perception

Most theories of L1 speech perception postulate that infants establish speech to sound categories based on the distribution of acoustic properties in their native language (Maye, Werker & Gerken, 2002). The following description draws from Morrison's work on speech perception (2006) and on Johnson's work with exemplar models (2006). If we consider the perception of vowel height by a native Spanish speaker, we can imagine that the listener is exposed to many distributions of Spanish vowels and that he deduces the distribution of these F1 values, over time establishing a category corresponding to each sound. Each time that a listener hears an instance of an exemplar, the connection to that category is strengthened so that by the time a listener's perception system has matured, most native vowel productions are correctly classified. By the time the listener has developed a lexicon in their native language, they are able to use lexical information to help classify auditory input. And if the

listener is literate in their L1, they can also use orthographic information to aid in the classification and storage of speech sounds.

1.2.2. L2/Cross-linguistic Speech Perception

Languages differ in the number of vowel sounds used to contrast meaning, and it has been shown that these differences have implications for how listeners perceive these sounds (Bradlow 1993, Fox et al. 1995, Levy & Strange 2008, Polka 1995, Scholes 1967 & 1968, Terbeek 1977). Several recent studies suggest that the L1 phonological system operates as a filter that accommodates linguistic input to its structure. Best's Perceptual Assimilation Model (Best 1994, Best 1995, and Best & Tyler 2007) emphasizes native language / second language perceptual similarity as a predictor of difficulties in the discrimination of non-native contrasts. In fact, studies have shown that speech perception is affected substantially by the phonological inventory of the languages spoken. Listeners who are not familiar with a phonological contrast used in another language may associate both members of the contrast with a single native language sound (see Kuhl, Williams, Lacerda, Stevens & Lindblom 1992). For instance, Johnson & Babel (2010) found that listeners of Dutch, which does not have a phonemic distinction for [s] and [ʃ], rated these fricatives as more similar to each other than AE listeners did.

Studies of cross-linguistic speech perception have also demonstrated that linguistic experience influences the perception of native and L2 speech sounds. The findings of Flege et al. (1994) demonstrated that the perceptual vowel space of native Spanish speakers who are relatively proficient in English differs from that of native Spanish speakers who are not proficient in English. Fox et al.'s study (1995) of the perception of English and Spanish vowels by English and Spanish listeners found that the vowel space of the proficient Spanish listeners was more English-like than that of the non-proficient Spanish listeners, suggesting that the perceptual dimensions used by listeners in identifying vowels may be gradually modified as proficiency in the L2 improves. In a study by Bradlow (1993) comparing English and Spanish listeners on three vowel contrasts ([i]/[e], [u]/[o], and [e]/[o]), she found that the groups displayed different response patterns to the same stimuli. She attributed these differences to the structural differences between the English and Spanish vowel spaces.

1.3. The Present Study

The present study examines the perception of English vowels by native Spanish- and English-speaking participants with varying levels and experiences in these languages.

1.3.1. The Perception of English Vowels

In particular, the perception of front vowels in AE that are ([e], [i]) and are not ([ɪ], [æ], [ɛ]) in the Spanish phonemic inventory were targeted in order to study the effects of non-native contrasts and linguistic experience on the perception of sounds. In a study by Flege, monolingual Spanish speakers most often identified English /i/ and /ɪ/ as Spanish /i/, English /æ/ as Spanish /a/, and English /ɛ/ as Spanish /e/ when asked to label words containing AE vowels using the letters <a e i o u> (Flege 1991). Additionally, Morrison's study of the perception of English vowels by L1 and L2 Spanish speakers found that Spanish learners of English confuse English /i/ and /ɪ/ and assimilate them to Spanish /i/ initially, and later /ɪ/ is assimilated to Spanish /e/. He hypothesizes that the initial association of English /ɪ/ with Spanish /i/ may be due to education and orthography rather than perceptual and phonetic factors (Morrison 2006). In their 1997 study of AE vowel perception, Flege et al. asked participants to identify the members of two vowel continua: [i]/[ɪ] and [æ]/[ɛ]. They found a significant difference in the perception of 'beat/bit' by native English speakers and native Spanish speakers, regardless of their proficiency in English. The current study probes these findings a bit further, using a non-orthographic and less direct means of measuring the perception of these vowels by native Spanish speakers with varying levels of English proficiency and native English speakers with varying levels of Spanish proficiency.

1.3.2. Heritage Language Speakers

In addition, the current study has as a primary aim the question of how heritage speakers of Spanish perceive English sounds. As the number of heritage Spanish speakers continues to rise in the US, more needs to be done to better understand their linguistic competence in both Spanish and English. Heritage speakers of Spanish, as proposed by Carreira (2004), differ from traditional second language learners because they have a family background in the heritage language or heritage culture. Traditionally, they are exposed to Spanish from birth and to English from birth or once they begin schooling in an English-speaking environment (age 4 or 5). In some fields, heritage speakers are often referred to as 'early bilinguals', therefore creating a contrast with 'late bilinguals', or bilinguals who learned their second language later in life.

Following Silva-Corvalán (1994) and Valdés (2000), first generation immigrants are those who were born outside of the US and moved to the US after the age of 11. They received some schooling in their native language and are often more proficient in their L1 than their L2. Second generation immigrants are those who were either born in the US to one or both parents who were born outside of the US, or they were born outside of the US and moved to the US before the age of 6. They traditionally received their education in their L2 language and are proficient in both their L1 and their L2. The heritage speakers in this study are first or second generation immigrants from Mexico and report that their families speak primarily Spanish or a mixture of Spanish and English. They have an average self-rating of 6.8 in English and 6.2 in Spanish (out of 7). Very little is known about how heritage Spanish speakers perceive and process sounds, and this study hopes to begin to shed light on that important research question.

2. Research Questions and Predictions

In the present experiment, perception of the American English front vowels [i], [ɪ], [e], [ɛ], and [æ] by speakers of monolingual, bilingual, and heritage Spanish and English was investigated. The primary aim of the study is to determine how heritage Spanish speakers perceive English vowels. While there have been no known studies on the perception of English vowels by heritage speakers of Spanish, the findings of Navarra et al's study (2005) shed some light on how heritage speakers will pattern in relation to bilingual and monolingual participants of an identical study. Navarra et al found that even early bilinguals of Catalan and Spanish (age of exposure to L2 was < 3 years) perceived vowels like monolingual speakers, based on their first language. They found that even proficient bilinguals categorize L2 sounds according to their L1 representations. Chang et al (2009) studied the phonetic space of phonological categories of heritage speakers of Mandarin Chinese, and they found that heritage speakers were closer than late L2 learners of Mandarin at approximating acute phonetic norms. While the heritage speakers did not perform identically to native speakers, they did maintain contrasts between similar L1 and L2 categories that bilinguals (late learners of Mandarin) did not. Based on the findings of these studies, and because the stimuli used in this study are English vowels, three of which are not found in Spanish, it was predicted that the heritage speakers will perceive sounds less like monolingual Spanish speakers and more like bilinguals.

In addition to the primary research question relating to how heritage Spanish speakers perceive English vowels, there are two secondary questions that the study attempts to answer. The first of these addresses the question of how the degree of English exposure and proficiency affect the perception of non-native vowel sounds ([æ], [ɛ], [ɪ]) for native Spanish speakers. Levy and Strange (2008), in their study on the perception of French rounded vowels (that are not in the American English phonemic inventory) by American English speakers, found that non-French-speaking American English participants had more difficulty discriminating French vowels than did those participants who had studied French. Fox et al. (1995) found that the vowel space used in the perception of English and Spanish vowels by native Spanish bilinguals differed based on their proficiency in English. Given these findings, it was expected the native Spanish speaking participants' ratings of the non-native vowels to vary based on their proficiency in English - where the monolingual Spanish speakers will

find those pairs that do not occur in Spanish to be more similar than the bilingual Spanish speakers will.

The final research question that this study addresses is how bilingual speakers perceive English vowels. More specifically, does being a bilingual speaker (L1 English or Spanish) affect how you perceive English vowels or do you perceive these sounds using only your L1 speech perception system? In their study of the perception of English and Spanish vowels by English and Spanish listeners, Fox et al (1995) found that the vowel space of Spanish listeners who were proficient in English was more English-like than that of non-proficient Spanish listeners. They concluded that the perceptual dimensions used by listeners in identifying vowels may be gradually modified as proficiency in the L2 increases. However, Navarra et al (2005), in their study of Spanish/Catalan early bilinguals, found that even proficient bilinguals categorize L2 sounds according to their L1 representations. The Catalan-proficient native speakers of Spanish performed indistinguishably from Spanish monolinguals in an implicit discrimination study, whereas the Spanish-proficient native speakers of Catalan responded differently. Based on these findings, it was predicted that bilingual speakers would perceive English vowels differently than their monolingual counterparts for some vowel pairs.

3. Methodology

A similarity rating task was used to study the effect of native and L2 sound inventories on the perception of sounds. This task was selected because it allows us to study several groups of participants using the same method, without them all being speakers of the same language(s). It also allows participants to make a quick judgment about a pair of sounds, without overloading their memory. An identification task, such as one in which participants identify the word containing the sound that they hear, was not used as we wanted to avoid having the participants consider the orthographic representations of the sounds - which are different in the two languages of this study. Previous studies have found that the current method can be used to uncover phonological differences between languages (cf. Boomershine et al. 2005, Johnson & Babel 2010). The following sections will describe the method used in the current study.

3.1. Participants

A total of 86 participants took part in the similarity rating experiment. The participants were divided into five groups based on their language background: monolingual Spanish, monolingual English, Native English/Advanced Spanish Bilingual, Native Spanish/Advanced English Bilingual, and Heritage Spanish speakers. For purposes of this study, monolingual participants were those who self-identified as being proficient in only their native language and who had not studied a second language above the basic level. It should be noted that the 'monolingual' participants in this study had not yet enrolled in a university foreign language course and reported no travel experience outside of the United States, so the researcher felt it was safe to consider them monolingual speakers of English. Bilingual participants were those who self-identified as being proficient in two languages - one being their dominant native language and the other being a second language that they learned in school (K - 12 and university) and through traveling/living in a country where the L2 is spoken. The native Spanish bilinguals had all lived in an English-speaking country, and the majority of the native English bilinguals had lived in a Spanish-speaking country. It should be noted that there was no significant difference in perceptual processing for those who had lived abroad versus those who had not. Heritage participants were those participants who grew up in the United States speaking Spanish at home and in the Hispanic community, and English in school and with their English-speaking peers. They acquired Spanish at birth and English at a very young age - upon moving to the United States or starting school in the US. Table 3.1 gives the total number of participants in each group, their mean self-rating for Spanish and English, their mean time in the US and Spanish-speaking countries, and their mean age at the time of the study. In completing the self-rating of their language skills, they were asked to rate their

production skills in the languages they speak and study/studied. The participants were all paid $10 for their participation in the study. None reported any current or past speech or hearing difficulties.

	N	Mean Self-Rating: English (1 - 7)	Mean Self-Rating: Spanish (1 - 7)	Mean Time in L2 Country (years)	Mean Age	Mean Age of L2 Start
Monolingual English	20	7.0	1.3	0.0	21	14
Monolingual Spanish	12	1.8	7.0	6.3	33	26
Heritage Spanish	17	6.8	6.6	19.7	22	2
Native English L2 Spanish Bilingual	19	7.0	5.6	0.3	23	10
Native Spanish L2 English Bilingual	18	6.1	6.8	10.2	30	11

Table 3.1: Participant information, including mean self-ratings for English and Spanish, time spent in US or Spanish-speaking country, mean age, and mean age at start of L2 study.

3.2. Stimuli

Five front vowels were used as the stimuli in this study: [i] (beet), [ɪ] (bit), [ɛ] (bet), [e] (bait), and [æ] (bat). (Note: For purposes of simplification, the AE vowel [iɪ] will be transcribed as [i] in this paper, as will [eɪ] as [e].) These vowels were selected because they are all part of the phonemic inventory of American English, but only two, [i] and [e], are found in Spanish, and as monophthongs instead of diphthongs, as in *p**i**so* ('floor') and *p**e**so* ('weight'), respectively.

Recordings were made of six native speakers of American English, 3 males and 3 females. The speakers were university students aged 18 to 25. None of the speakers reported having an advanced knowledge of any language other English, and estimated their speaking ability for the foreign language studied in high school/college to be at the beginner level. Recordings were made in a sound-attenuated booth using an Audio-Technica ATR20 microphone and Marantz PMD-660 Compact Flash recorder. Speakers were presented with lists of sentences to read. Each sentence had the format "Now say b_t again". (Note: The consonantal context in which vowels are presented has been shown to influence listeners' perception of both native (Nearey 1989) and non-native sounds (Gottfried 1984, Levy & Strange 2008). Thus, the consonantal context was kept the same for this study, as surrounding context was not a factor of interest in the current experiment.) In each sentence the V consisted of one of the AE front vowels being studied: /i, ɪ, ɛ, e, æ/. We then extracted the vowel from each phrase and selected the clearest token of each (normally the second recording), resulting in thirty vowel tokens (five vowels by six speakers). In order to control the amplitude across tokens and speakers, the peak amplitude was equated for each of the tokens.

In order to select the three speakers whose tokens were to be used in the experiment, an identification task was conducted. An online survey was created using Select Survey software, and participants were asked to listen to a sound and then select the word from which it was most likely extracted. For instance, the participant would hear [æ] and then select the word from the list that sounded most like the sound that they heard ('bat'). The identification task was completed by 24 native speakers of American English. Two female speakers (f2 and f3) and one male speaker (m3) had the highest correctly identified responses for the vowels that they had produced, so those three speakers' tokens were selected as the stimuli for the current study. Table 3.2 provides the percent correct by

speaker for each of the tokens used in the study, while Table 3.3 illustrates the F1 and F2 values for the three speakers.

	[i] (beet)	[ɪ] (bit)	[ɛ] (bet)	[e] (bait)	[æ] (bat)
speaker f2	92.9%	92.9%	96.4%	96.4%	92.9%
speaker f3	96.3%	96.3%	85.2%	100%	85.2%
speaker m3	100%	96.3%	88.9%	92.6%	96.3%

Table 3.2. Results of stimulus identification study. Percent correct by vowel for each speaker.

	speaker f2		**speaker f3**		**speaker m3**	
	F1	**F2**	**F1**	**F2**	**F1**	**F2**
[e]	490	2700	520	2500	470	2170
[æ]	960	1760	900	2100	790	1800
[i]	410	2880	440	2770	340	2360
[ɛ]	750	1910	810	1960	740	1760
[ɪ]	542	2360	580	2050	400	1920

Table 3.3: Average Formant 1 and Formant 2 vowel spaces (in Hz) of American English vowel stimuli, produced by the three speakers in this study.

3.3. Procedure

In this task, participants were told that they would hear a pair of sounds and were asked to rate how similar they sounded using a 5-point scale, where 1 was 'very similar' and 5 was 'very different'. They were seated at a computer that was connected to a five-button response box, and heard the stimuli through headphones. The pairs were presented in a different random order for each participant, using E-Prime software (v. 1.2; Psychological Software Tools, Pittsburgh, PA). The listeners heard pairs of stimuli, separated by one second of silence, such as [æ] <1 sec silence> [ɛ]. The talker was the same for every pair, so that participants were not rating how similar or different each of the talkers was instead of the actual vowel sound itself. The participants were given four practice trials, and then the opportunity to ask questions before proceeding to the test blocks. There were three test blocks of 60 trials each (30 pairs x 2), with one block per speaker (180 trials in total). The participants were given 5 seconds to respond by pushing a button on the response box. They received no feedback in this experiment. After completing the similarity rating task, subjects completed a background questionnaire.

4. Results and Discussion

To analyze the results, the rating scores for each participant were normalized to compensate for differences in use of the 5-point scale (e.g. avoiding use of the endpoints, etc.). The scores were normalized using a standard z-score transformation (Z = score-mean / SD), such that each participant's scores were centered around 0, with scores above zero indicating "more different" and scores below zero indicating "more similar." The normalized results for the 'different' pairs (the normalized ratings for the 'same' pairs were all well below 0) and participant groups are shown in Figure 4.1.

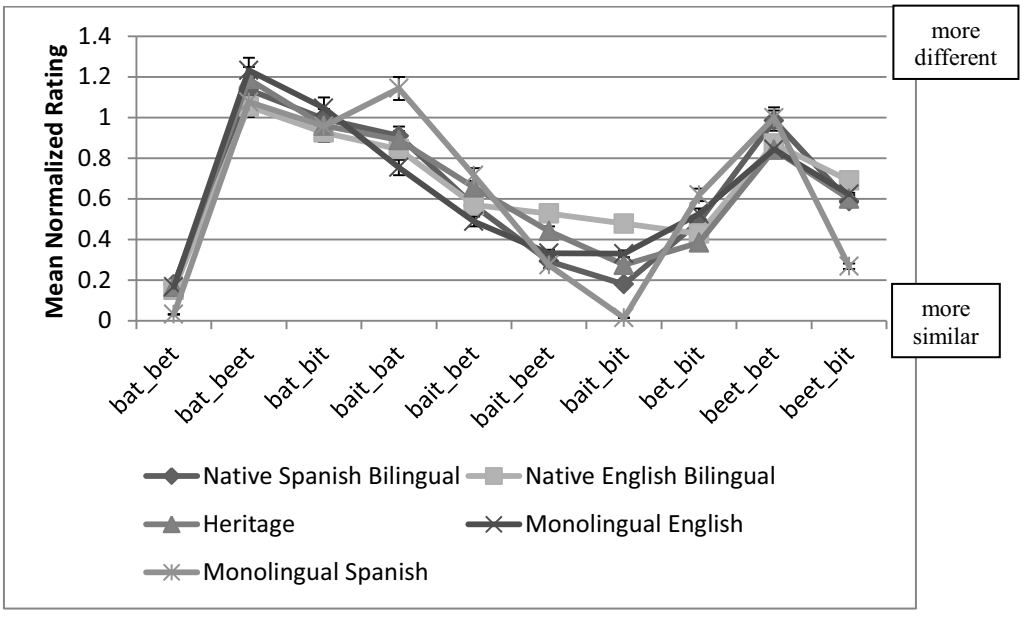

Figure 4.1: Mean normalized similarity rating by vowel pair and participant group for different pairs.

A repeated measures analysis of variance showed that there was a main effect of pair, $F(9,720) = 102.31$; $p < 0.01$. That is, regardless of native language or L2 proficiency, the pairs were not all rated the same. As can be seen from Figure 4.2, the following pairs were rated as more similar than the other pairs, regardless of participant group:[æ]/[ɛ] (bat/bet), [e]/[i] (bait/beet), [e]/[ɪ] (bait/bit).

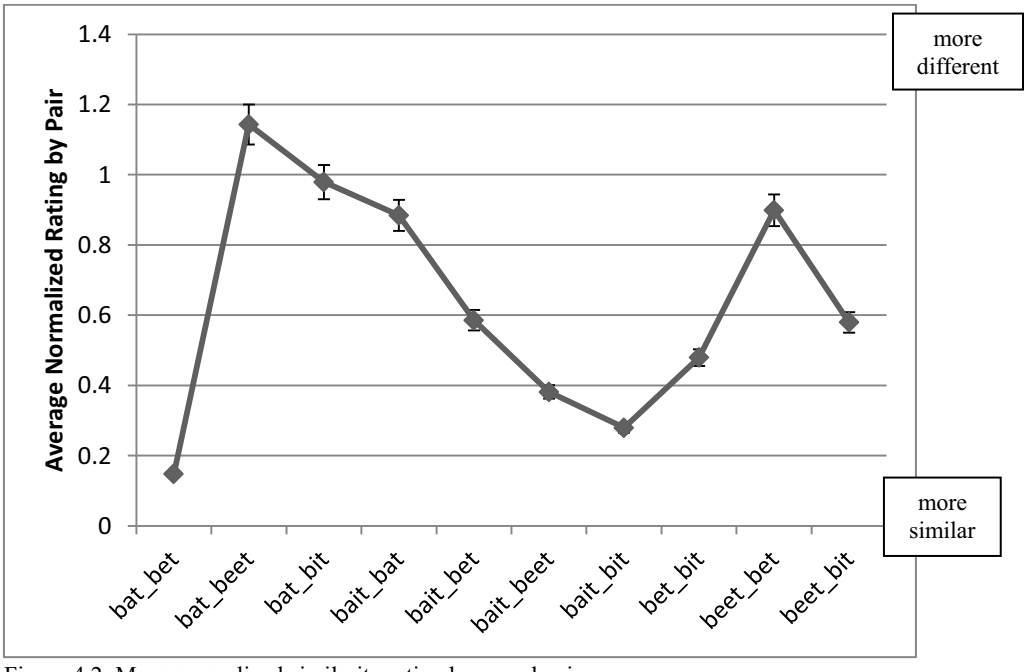

Figure 4.2: Mean normalized similarity rating by vowel pair

There was also a significant pair by group interaction effect, $F(36,720) = 2.159$; $p < 0.01$, meaning that a participant's response to a given pair was dependent on the language group he was in. There was a significant difference in similarity for at least two groups for each vowel pair, except [æ]/[ɛ]

(bat/bet), [æ]/[ɪ] (bat/bit), [e]/[i] (bait/beet), and [ɛ]/[ɪ] (bet/bit). The ratings for these four vowel pairs did not reach a significant difference for any of the participant groups.

The two groups of bilingual participants (native English / advanced Spanish and native Spanish / advanced English) rated all of the vowel pairs very similarly except the pairs [e]/[i] (bait/beet) and [e]/[ɪ] (bait/bit), shown in the figure below. The native English speaking bilingual participants found these pairs to be more different than did the native Spanish speaking bilinguals. An independent samples t-test showed that this difference was significant for the pair [e]/[ɪ], $t = -3.56$; $p < 0.01$; $df = 35$, and approached significance for the pair [e]/[i], $t = -1.97$; $p = 0.059$; $df = 26$. For all other vowel pairs, the two bilingual groups patterned the same. These results suggest that for Spanish/English bilingual speakers their native language was not a significant factor in rating how similar English vowels sounds are, except for one pair.

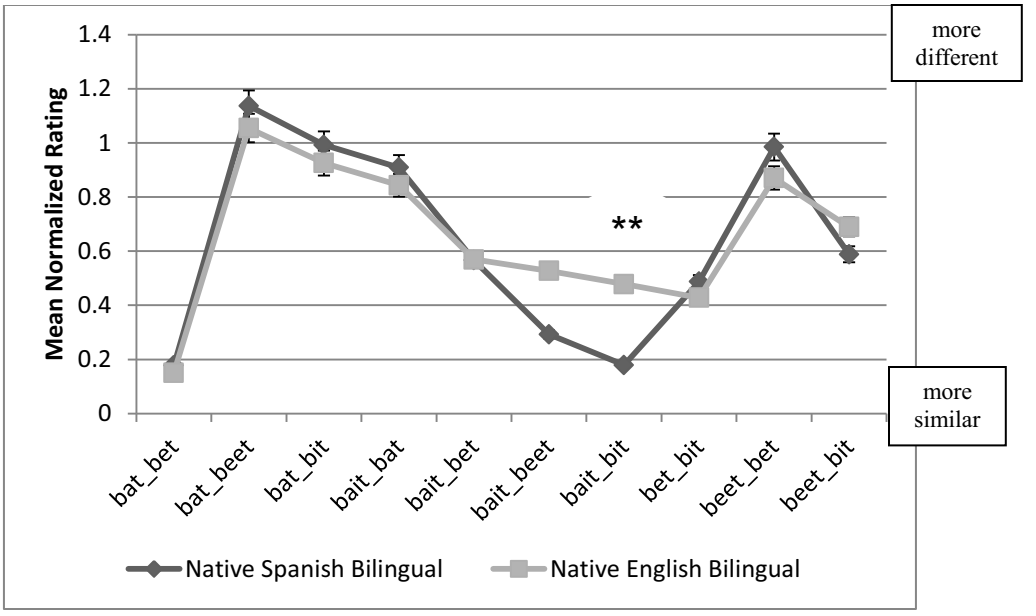

Figure 4.3. Mean normalized vowel ratings for the bilingual participants (native English / advanced Spanish and native Spanish / advanced English). Pairs marked with "*" showed a significant difference in a planned comparison at $p < 0.05$, and those with "**" showed a significant difference in a planned comparison at $p < 0.01$.

The heritage Spanish speakers and the native Spanish speaking bilinguals rated all of the vowel pairs similarly. Subsequent planned comparison independent samples t-tests showed that their ratings were not significantly different for any vowel pair. The same was true for the heritage speakers and the native English speaking bilinguals, except for the vowel pair [e]/[ɪ] (bait/bit). The native English speaking bilingual participants found that pair to be more different than did the heritage speakers, and an independent samples t-test showed that this difference was significant, $t = 2.89$, $p < .0.01$; $df = 34$. It is interesting to note that both the heritage and native Spanish-speaking bilinguals found this pair to be more similar than did the native English-speaking bilinguals. Figure 4..4 illustrates these results.

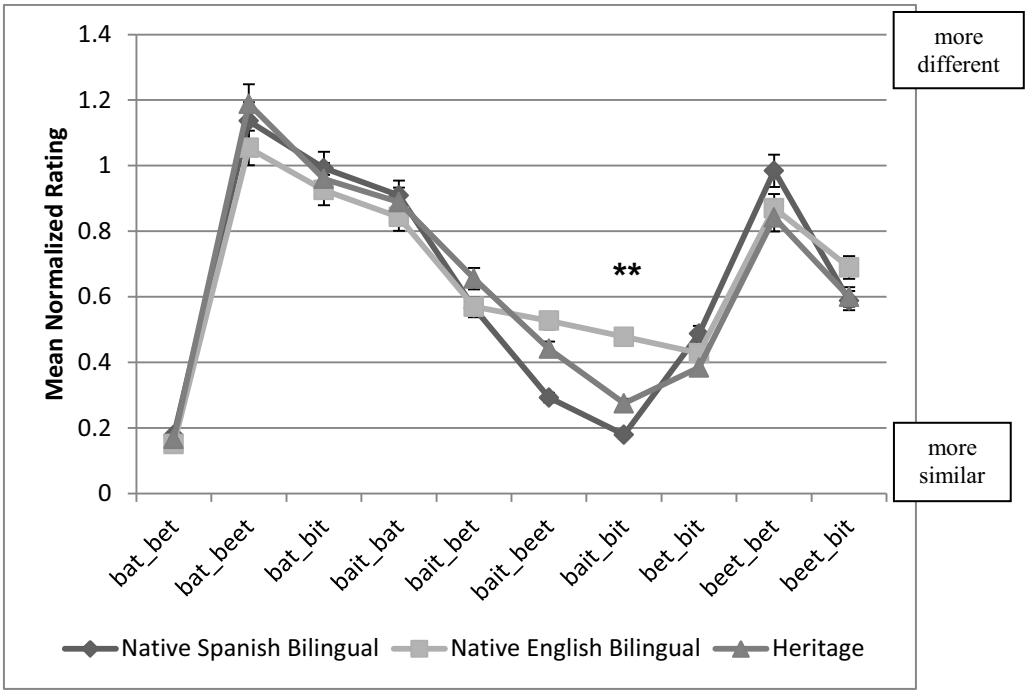

Figure 4.4. Mean normalized vowel ratings for the bilingual participants (native English / advanced Spanish and native Spanish / advanced English) and heritage Spanish participants. . Pairs marked with "*" showed a significant difference in a planned comparison at $p < 0.05$, and those with "**" showed a significant difference in a planned comparison at $p < 0.01$.

The heritage group and the monolingual Spanish group, however, had quite a few differences in similarity ratings. The heritage speakers found the pair [e]/[æ] (bait/bat) to be more similar than did the monolingual Spanish speakers. An independent samples t-test showed that this difference was significant, $t = -3.76$; $p < 0.01$; $df = 26$. The heritage speakers also found the pair [i]/[ɛ] (beet/bet) to be more similar than did the monolingual Spanish speakers, with an independent samples t-test showing that this difference was significant, $t = -2.15$; $p < 0.05$; $df = 26$. The monolingual Spanish speakers found both [e/ɪ] (bait/bit) and [i]/[ɪ] (beet/bit) to be more similar than the heritage speakers did. Independent samples t-tests showed that these differences were significant, $t = 2.53$; $p < 0.05$; $df = 26$, and $t = 2.25$; $p < 0.05$; $df = 13.6$, respectively. These results suggest that for a number of vowel pairs, the heritage speakers pattern more like bilingual speakers than monolingual Spanish speakers. In fact, there were no significant differences between the heritage speakers and the native Spanish speaking bilingual participants, but there were several significant differences between the heritage speakers and their monolingual Spanish counterparts. Figure 4.5 illustrates these differences.

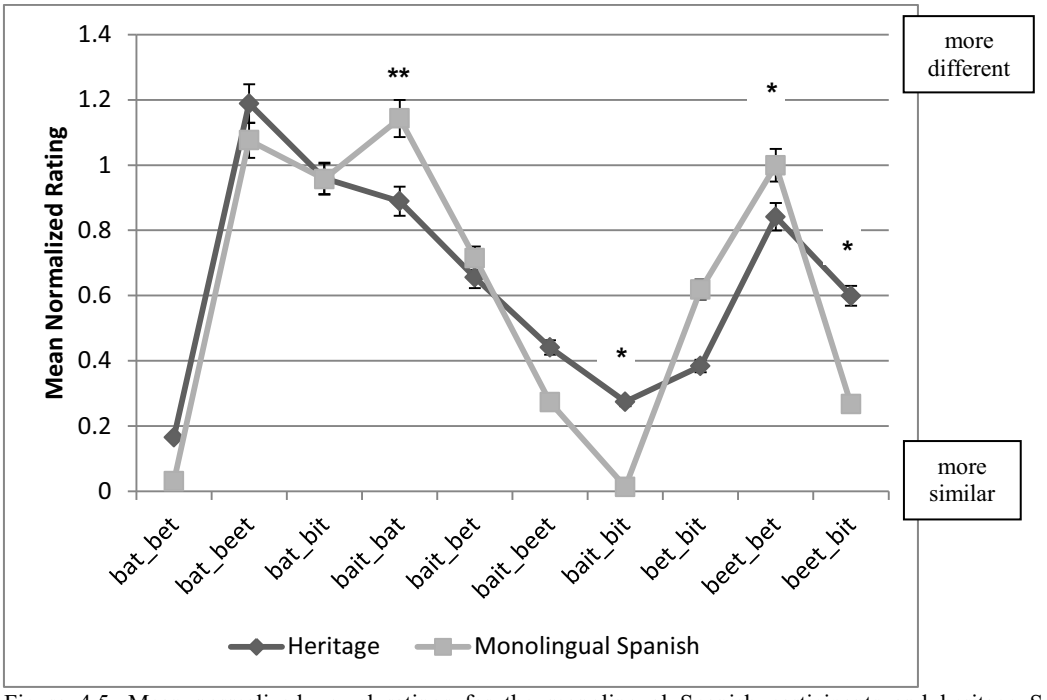

Figure 4.5. Mean normalized vowel ratings for the monolingual Spanish participants and heritage Spanish participants. . Pairs marked with "*" showed a significant difference in a planned comparison at $p < 0.05$, and those with "**" showed a significant difference in a planned comparison at $p < 0.01$.

The native Spanish-speaking bilinguals and the monolingual Spanish speakers patterned significantly differently for two of the vowel pairs. The bilinguals found the pair [e]/[æ] (bait/bat) to be more similar than did the monolingual Spanish speakers. An independent samples t-test showed that this difference was significant, $t = -3.58$; $p < 0.01$; $df = 21.4$. On the other hand, the monolingual Spanish speakers found [i]/[ɪ] (beet/bit) to be more similar than the bilingual speakers did. This difference was significant, as shown by an independent samples t-test: $t = 2.33$; $p < 0.05$; $df = 27$. These results suggest that being more experienced and proficient in English determines how English vowels are perceived by native Spanish speakers. The finding that the monolingual Spanish speakers perceived [i] and [ɪ] to be more similar than the bilingual speakers is not surprising, as these vowels are phonetically very similar and are often considered to be the most difficult vowel distinction in English for native Spanish speakers to produce (Flege et al, 1997). The results for the [e]/[æ] pair will be discussed in the next section.

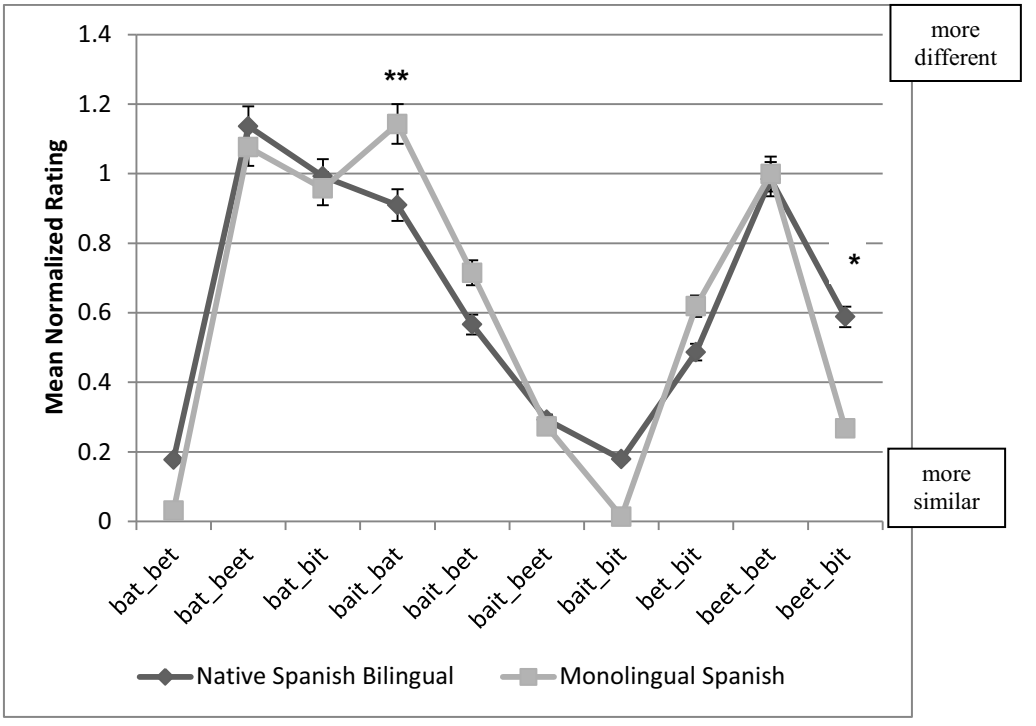

Figure 4.6. Mean normalized vowel ratings for the bilingual native Spanish participants and monolingual Spanish participants. Pairs marked with "*" showed a significant difference in a planned comparison at $p < 0.05$, and those with "**" showed a significant difference in a planned comparison at $p < 0.01$.

As expected, the monolingual Spanish speakers and monolingual English speakers rated many of the vowel pairs differently, as seen in the figure below. The monolingual Spanish speakers found three pairs to be more different compared to the ratings of the monolingual English speakers. The pairs that were more different for the Spanish speakers are [e]/[æ] (bait/bat), [e]/[ɛ] (bait/bet), and [i]/[ɛ] (beet/bet). Independent samples t-tests show that these differences are significant, $t = -4.84$; $p < 0.01$; $df = 28.5$, $t = -2.38$; $p < 0.05$; $df = 29$, and $t = -2.60$; $p < 0.05$; $df = 29$, respectively. The monolingual Spanish speakers found two pairs to be more similar than did the monolingual English speakers. These pairs are [e/ɪ] (bait/bit) and [i]/[ɪ] (beet/bit). Independent samples t-tests show that these differences are significant $t = 2.56$; $p < 0.05$; $df = 29$, and $t = 2.81$; $p < 0.01$; $df = 29$, respectively. These results indicate that monolingual English and Spanish speakers perceive English vowels differently, as expected.

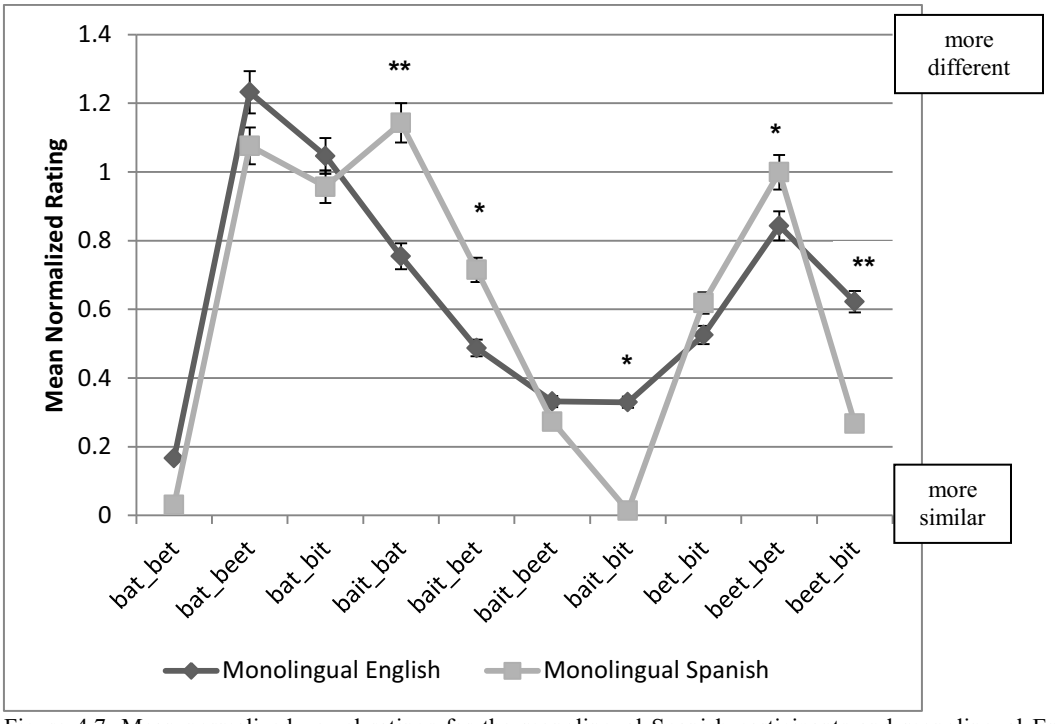

Figure 4.7. Mean normalized vowel ratings for the monolingual Spanish participants and monolingual English participants. . Pairs marked with "*" showed a significant difference in a planned comparison at $p < 0.05$, and those with "**" showed a significant difference in a planned comparison at $p < 0.01$.

5. Conclusion

Results of the present study revealed that English-speaking and Spanish-speaking listeners' performance on English contrasts involving front vowels varied as a function of their proficiency in their second language, the particular vowel contrast, and their native language. The research questions posed at the beginning of the paper are readdressed in light of the experimental findings.

As predicted, the heritage speakers of Spanish patterned identically to the native Spanish-speaking bilinguals. In the current task, there was not a significant difference in the vowel pair ratings for those participants who grew up speaking both Spanish and English (i.e. heritage speakers) and those who learned English in an academic setting later in life (i.e. native Spanish-speaking bilinguals). The bilingual participants started learning English at age 11, on average, while the heritage speakers were exposed to English at age 2, on average. From the results of this study, it seems that heritage speakers perceive English vowels in the same way that bilingual speakers do. The author predicts, though, that there are significant differences between the two groups in the case of production of these same vowels (see Chang et al, 2009). A follow-up production study, in which heritage speakers and bilingual speakers are asked to produce English vowels, is underway. It will be interesting to see if heritage speakers are able to produce the [i]/[ɪ] distinction, as Flege et al (1997) found that there was not a significant difference in production of experienced and inexperienced native Spanish speakers of English.

Returning now to the second research question – the one addressing English proficiency level and non-native speech perception, the results of the current study suggest that the amount of English-language experience the native Spanish speakers had influenced how they perceived English vowels. The author posits that these differences occurred for orthographic, phonological, and phonetic reasons. The Spanish speakers who were inexperienced with English perceived the [i]/[ɪ] pair as being more similar than did any other group. This can be explained by their close proximity in vowel space and phonetic similarity and the fact that Spanish does not have [ɪ] in its inventory, so the speakers without English experience had no category for this sound and therefore considered it to be similar to [i], a

sound that does occur in Spanish. In his 1991 study, Flege had Spanish monolinguals use the letters <a e i o u> to label vowels in English words. He found that the participants most often classified English /i/ and /ɪ/ as Spanish /i/ - a finding that is comparable to the similarity ratings for [i] and [ɪ] by monolingual Spanish speakers in the current study. In Morrison's 2008 study of the perception of vowels by native Spanish speakers, he found that for Mexican-Spanish listeners, three quarters of the portion of the stimulus space for which the English listeners' modal response was English /ɪ/ was identified as Spanish /i/ and one-quarter as Spanish /e/ (Morrison, 2008). The current findings are in line with those of Morrison (2008) and Flege (1991).

The Spanish speakers who were inexperienced with English perceived the [æ]/[e] pair as being more different than did any other group. One could argue that this is due to orthography; as these sounds are quite often both spelled in English with the letter <a> (i.e. fat, fate). Thus, the Spanish speakers with English experience found this pair to be more similar than did the speakers without English experience due to the way the sounds are represented orthographically in English. It should be noted, however, that the participants were instructed to rate the sounds based on how they sounded, and thus, there is no evidence to suggest that they were associating the aural stimuli with written words during the experimental trials. That said, The inexperienced Spanish speakers, however, found this pair to be more different - most likely due to the fact that Spanish does not have the sound [æ], so the Spanish speakers perceived it to be part of the Spanish [a] category. Flege (1991) found that the monolingual Spanish participants in his study classified realizations of English /æ/ as Spanish /a/. Therefore, it is argued that the monolinguals were actually rating two Spanish vowels that are very contrastive, [e] and [a], and thus found them to be more different than did the bilingual Spanish speakers, who were hearing the English vowels, which are acoustically similar, rather than the Spanish vowels.

The final research question addressed by this study is that of the effect of being bilingual on speech perception. This study found that bilingual speakers' native language has some effect on how vowels are perceived. The bilingual participants patterned nearly identically for all vowel pairs except for [e]/[i] and [e]/[ɪ]. For both pairs, the native English bilinguals found these pairs to be more different, with a significant difference in rating for the latter pair and a trend toward significance for the former. In fact, the native Spanish bilinguals patterned nearly identically to the monolingual Spanish speakers for these two pairs. Following Morrison's (2006, 2008) research on the perception of vowels by native Spanish speakers, this result is not completely surprising. In his study, native speakers of Mexican-Spanish identified English /ɪ/ as Spanish /i/ and, to a lesser extent, Spanish /e/. For the Peninsular-Spanish speakers in his study, they identified English /ɪ/ as Spanish /e/. Therefore, the finding of the current study is not unexpected. Also, given that the stimuli for this study were English vowels, these pairs of sounds are contrastive for native English bilinguals, and thus they rated them as being more different, while the native Spanish bilinguals rated them as monolingual Spanish speakers did. However, there were two vowel pairs that were rated differently by the Spanish bilinguals and monolinguals ([e]/[æ] and [i]/[ɪ]). For the native Spanish bilinguals, their experience with English gave them more vowel categories to use during the perception of English vowels, thus altering their rating of these vowels (i.e. [i] and [ɪ] are contrastive in English). More studies need to be done comparing the perception of vowels by bilingual participants, including studies that have both English and Spanish vowels as part of the stimulus set.

The findings from this study have implications for models of cross-language speech perception. The results support the view that adults who learn an L2 become able to perceive some L2 vowels more accurately as they gain experience in the L2. The heritage speakers patterned significantly differently from the monolingual Spanish speakers for four of the vowel pairs, while the bilingual Spanish speakers only patterned significantly differently from the monolingual Spanish speakers for two of the pairs. While the heritage and bilingual speakers patterned similarly, the difference between the two groups when compared with the monolingual Spanish speakers' ratings indicates that being exposed to an L2 from a very early age (average age of 2) does affect how L2 sounds are perceived, especially those that are not found in the L1. These findings have implications, as well, for public school curricula, especially at a time when foreign language programs are being cut in elementary and middle schools nationwide.

Further research is needed to better understand how vowel perception varies based on the age of L2 exposure. This study begins to shed light on this issue, but more perception studies need to be conducted comparing heritage Spanish speakers with monolingual speakers, bilingual speakers, and L2 learners of Spanish. Especially useful would be perception studies using both English and Spanish vowels in which heritage speakers participated along with the traditional groups of subjects. In addition, research needs to be done on how heritage Spanish speakers produce both Spanish and English vowels, and how their production differs from that of monolingual, bilingual, and L2 learners' production of those same phones.

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