THE PERCEPTION OF ENGLISH VOWELS BY NATIVE SPANISH SPEAKERS

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Many studies have shown that a person's perception of second language (L2) sounds is affected by previous language experience, and there are multiple theories which attempt to account for this fact (Flege, 1995; Kuhl, 2000) One theory, the Perceptual Assimilation Model for Language Learners (PAM-L2), states that the difficulty of accurate L2 perception can be predicted through an assessment of the interaction between the first language (L1) and L2 sound systems (Best & Tyler, 2007). Specifically, the PAM-L2 framework makes predictions for the level of discrimination difficulty based on how the L2 tokens of any given contrast map onto language learners' L1.

This study investigated the effect that previous language experience has on L1 Spanish speakers' perception of L2 English vowels and interpreted the results in the framework of PAM-L2. Twelve native Spanish speakers from the University of Pittsburgh completed a vowel assimilation task which evaluated the perceived similarity between L2 English vowels and L1 Spanish vowels. Next, the participants were tested on their ability to distinguish distinct vowel categories in an AX discrimination task. Finally, they participated in a forced identification task to assess their ability to correctly label English speech sounds.

The results from the discrimination task supported PAM-L2's predictions of discrimination difficulty for only six of the ten contrasts analyzed. Moreover, the results suggest

that any L2 vowel contrast can be easy *or* difficult to discriminate, regardless of how the individual vowels of the contrast assimilate to the L1.

Results from the forced identification task showed that three of the four most inaccurately discriminated vowel contrasts contained one token that was misidentified as the other member of the contrast more frequently than it was correctly identified. For example, in the /i-ɪ/ contrast, /i/ was identified as /ɪ/ in 54% of all cases, while it was correctly labeled only 44% of the time.

The results from this study demonstrate that the PAM-L2 framework inadequately predicts levels of discrimination difficulty for L2 vowel contrasts for L1 Spanish learners of English. Future research must explore ways to analyze L2 speech perception that do not rely exclusively on vowel assimilation patterns.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PREFACE

I would like to thank the members of my committee: Alan Juffs and Claude Mauk, for the time they spent reading and making comments to earlier drafts of the MA Thesis. I would also like to thank my graduate advisor, Marta Ortega-Llebaria, whose support and guidance were crucial to the completion of this paper.

1.0 INTRODUCTION

The experience with our native language affects our perception of nonnative speech sounds in a systematic, predictable manner. Just as an adult does not perceive sounds the same way an infant does, a monolingual will not perceive a nonnative speech contrast the same as a bilingual (Best & Tyler 2007). There are multiple theories that explain the relative difficulty of perceiving nonnative speech sounds based on one's linguistic experience. One of these theories, the Perceptual Assimilation Model for Language Learners (PAM-L2), accounts for varying degrees of difficulty by looking at the interaction of learners' first language (L1) and second language (L2) sound systems (Best & Tyler 2007). This interaction is assessed through an assimilation task where participants categorize L2 sounds onto the sounds of their native language. The different patterns of categorization from this task are believed to predict the varying levels of difficulty in the perception of second language sounds. The purpose of this thesis is to examine PAM-L2's predictions by comparing results from the mapping tests to the outcome of the categorical discrimination and forced identification tasks presented to native Spanish speakers learning English.

1.1 THE PERCEPTUAL ASSIMILATION MODEL FOR LANGUAGE LEARNERS (PAM-L2)

The PAM-L2 posits that the L1 and L2 sound systems interact on both the phonetic and phonological levels (Best & Tyler 2007). The researchers explain how the phonological system is crucial to nonnative speech perception because "listeners may identify L1 and L2 sounds as functionally equivalent" even if the phonetic representations are dissimilar. For example, French /ʁ/ and English /ɹ/ have little in common phonetically, but are considered to perform the same function phonologically.[1] Therefore, according to PAM-L2, English-French learners would form a new phonetic category for the L2 rhotic under the already existing L1 phonological category, /ɹ/ or /ʁ/, respectively.

Support for the hypothesis that L1 and L2 phonetic categories exist in the same phonological space comes from Antoniou et al. (2010). After analyzing the voice onset time (VOT) of /p t b d/ produced by sequential L1-Greek/L2-English bilinguals, the authors noticed that the bilinguals were indistinguishable from Greek monolinguals, meaning that their knowledge of English did not affect the way they spoke Greek. Conversely, they found that their experience with Greek only affected their VOT production of word-medial stops in English. The ability of the bilinguals to produce the appropriate VOTs in numerous contexts in two languages was interpreted by the researchers as the existence of two distinct, language-specific phonetic categories present in one phonological area.

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[1] French /ʁ/ and English /ɹ/ are represented the same orthographically which may add to the perceptual connection between these two sounds. Citing Ladefoged & Maddiesson (1996) and Lindau (1985), Best & Tyler (2007) state it is possible that the two rhotics are represented identically because they follow similar patterns in the two languages like, "syllable structure, phonotactic regularities, and allophonic and morphophonemic alternations."

The ability of a language learner to establish new phonological categories is based, in part, on the perceived similarities and differences of the L1 and L2 sounds; specifically how the tokens of an L2 contrast assimilate onto L1 segments (Best & Tyler, 2007). The four different assimilation patterns described by the PAM-L2 are as follows:

1. *Single-Category Assimilation* (SC): The difference between the two sounds in an L2 contrast will be difficult to perceive if they are both mapped onto a single L1 category with equal degrees of goodness.

2. *Two-Category Assimilation* (TC): It will be easy for an L2 learner to discriminate between the two sounds of an L2 contrast when each one is mapped onto a different L1 category.

3. *Category Goodness Assimilation* (CG): There will be moderately good discrimination for the two sounds of an L2 contrast that are mapped onto the same L1 category but with different degrees of goodness.

4. *Uncategorized-Uncategorized Assimilation* (UU): A sound is uncategorized when it isn't assimilated well into just one category. The ease/difficulty in the discrimination of these two sounds will depend on how close they are to each other in perceptual space. The closer they are, the more difficult it will be to discriminate them.

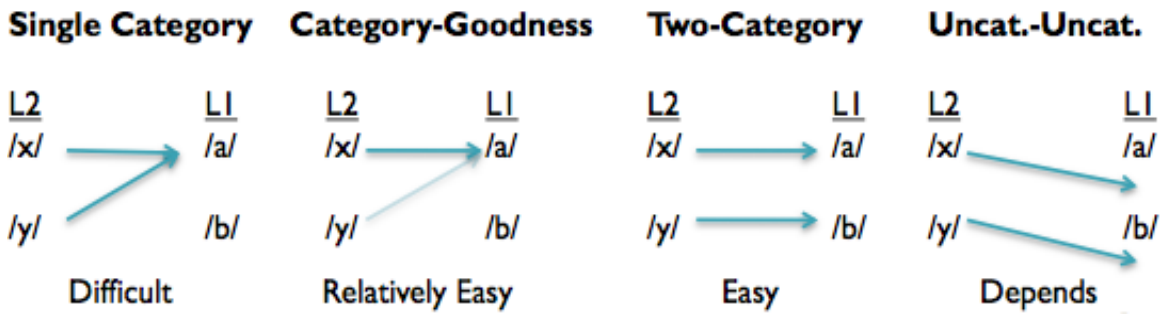

Figure 1: Illustration of PAM-L2 assimilation patterns. The figure above displays the assimilation patterns described by PAM-L2 and the level of predicted discrimination difficulty of an L2 contrast containing the sounds 'X' and 'Y'. In the Category-Goodness assimilation, the strength of the assimilation is represented by the darkness of the arrows.

Numerous studies have been done investigating L1 Spanish speakers' perception of English vowels, but I did not find any that tested the accuracy of PAM-L2's predictions. However, L2 English perception studies assessing these predictions have been performed on native Catalan speakers (NC) (Cebrian, 2008; Rallo Fabra & Romero, 2012) and native Italian (NI) speakers (Flege & McKay, 2004).[2] The results from these studies have been mixed. While PAM-L2 is able to explain the level of discrimination difficulty for certain vowel pairs, it falls short with others.

Rallo Fabra & Romero (2012) looked at how native Catalan speakers perceived four L2 English vowel contrasts through the PAM-L2 framework. One of the contrasts investigated was the tense-lax vowel pair, /i/-/ɪ/. Both the English /i/ and /ɪ/ were assimilated to Catalan /i/, at 96% and 39.5%, respectively. According to Best and Tyler (2007) then, an /i-ɪ/ contrast would fit the guidelines for the category-goodness assimilation pattern, resulting in relatively good discrimination between the two tokens. Results from Rallo Fabra & Romero (2012) support this prediction. Flege & McKay (2004) found similar results while investigating the perception of

[2] Italian and Catalan have the same seven contrasting vowels: /i, e, ɛ, a, ɔ, o, u/

English by native Italian speakers who had spent three months in Canada. In their study, English /i/ and /ɪ/ were also assimilated onto the same L1 category /i/ at different rates, 87% and 65%, respectively. The NI speakers were able to distinguish the two tokens with roughly 81% accuracy.

However, the PAM-L2 was inadequate at explaining why the sounds in the /ɛ-æ/ contrast were so difficult for native Catalan and Italian speakers to discriminate. In Rallo Fabra & Romero (2012), the PAM-L2 predicted that English /ɛ/ and /æ/ would be easy for native Catalan speakers to distinguish because each was assimilated onto a different Catalan category: Eng/ɛ/ assimilated to Cat/ɛ/ and Eng/æ/ assimilated to Cat/a/. But this contrast turned out to be quite difficult. Interestingly, NI speakers assimilated English /ɛ/ and /æ/ differently than the NC speakers. Instead of being categorized onto two different Italian categories, both English /ɛ/ and /æ/ were perceived as most similar to the Italian category, /ɛ/, though at different frequencies. Even with the change in assimilation pattern, the PAM-L2's prediction of 'relatively easy assimilation' didn't come to fruition because as Flege & McKay (2004) mention, NI speakers were unable to discriminate these two sounds at a rate significantly better than chance.

When native Catalan speakers completed a vowel assimilation task in Cebrian (2008), he found a similar category-goodness pattern for the /i-ɪ/ contrast (English /i/ → Catalan /i/, 99%; English /ɪ/ → Catalan /i/, 66%). However, he noted that this led to poor vowel identification scores in a forced choice task. He claimed that even though English /i/ was considered to be nearly identical to Catalan /i/, it did not result in accurate identification like the other strongly assimilated English vowels /ɛ/ and /e[ɪ]/ because its perception had been skewed by the fact that a new category had to be created distinguishing English /i/ from English /ɪ/, a nonexistent contrast in Catalan. This alleges that we cannot simply rely of F1/F2 measurements when discussing

perceptual similarity because we do not acquire vowel sounds independently from other sounds, but rather we acquire them as part of a "system of contrasting categories."

Flege & MacKay (2004) presented a series of L2 change/no-change contrasts to native Italian (NI) speakers and found that the perception of participants with low-L1 use did not differ significantly from that of the native English speakers in their discrimination accuracy of /ɒ-ʌ/, /ɛ-æ/, and /i-ɪ/. The authors claimed that these NI speakers had established new phonetic categories that high-L1 users did not. Best and Tyler (2007) interpret these results as supportive of the PAM-L2, which claims the ability of a learner to establish new L2 categories remains intact throughout one's lifetime and may be affected by the amount of practice and exposure one has with the L2.

However, there have been instances where L2 sounds are perceived accurately, not because of a newly formed category, but rather because they are consistently heard as good instances of the L1 category (Cebrian, 2008). In an effort to pinpoint when native Catalan speakers established English vowel categories instead of simply using the closest L1 category, Rallo Fabra & Romero (2012) analyzed how speakers discriminated L2-L2 and L1-L2 contrasts. In the English-Catalan contrasts the participants were unable to accurately distinguish English /i/ from Catalan /i/ or English /u/ from Catalan /u/. However, the same native Catalan speakers with intermediate and high levels of English were able to discriminate English /ɪ/ from Catalan /i/ and English /ʊ/ from Catalan /u/. This led the authors to believe that while new phonetic categories for English /ɪ/ and /ʊ/ could conceivably have been established, English /i/ and /u/ were considered accurate exemplars of Catalan /i/ and /u/ and therefore no new L2 categories needed to be formed.

1.2 SPANISH AND ENGLISH VOWELS: A COMPARISON

Native Spanish speakers learning English are interesting candidates for testing the hypotheses presented by PAM-L2 because of the large difference in the number of vowels in each language's inventory. The Spanish language has five vocalic phonemes (/i, e, a, o, u/) that remain stable throughout multiple dialects of Spanish (Morrison & Escudero, 2007) and are closely tied to the graphemes *i, e, a, o, u*. This lack of variation between orthography and pronunciation in Spanish is quite different from what we see in English.

English uses the same writing system as Spanish, but instead of having a one-to-one correspondence between grapheme and pronunciation, the five written vowels, in combination or alone, represent eleven phonemes in stressed syllables /i, ɪ, e, ɛ, æ, ɑ, ɔ, ʌ, o, ʊ, u/.[3] For example, English /i/ is represented orthographically in a number of ways: *h<u>ea</u>l, b<u>ee</u>t, y<u>ie</u>ld, conc<u>ei</u>ve, k<u>ey</u>,* and *m<u>e</u>*, but never by the single grapheme *i.* English /ɪ/, on the other hand is always represented by the grapheme *i*. Morrison (2009) hypothesizes that the multiple ways of representing the same phoneme in English orthography may inhibit the correct perception of the tense-lax pair /i/-/ɪ/ by native Spanish speakers that have experience reading in their L2.

Numerous studies have been done on native Spanish speakers' perception of English tense-lax vowel contrasts, namely /i-ɪ/, /e-ɛ/ and /ʊ-u/ (Cebrian, 2006; Morrison, 2009; Gulinello, 2010). What studies have found is that these English language learners often cannot discriminate between tense-lax pairs based on the vowels' spectral quality (Gulinello, 2010; Cebrian, 2006; Flege & MacKay, 2004) and therefore learn to rely on temporal cues to differentiate the two in both their perception and production. (Morrison, 2009). This shows the

[3] All of these, with the exception of /ʌ/ will be examined over the course of this investigation.

Spanish speakers using a method of discriminating phonemes that is not used in their L1 or by the native speakers of the target language. Even though English tense-lax pairs do differ in duration, it is not the defining characteristic used by Native English speakers to make any distinctions between vocalic categories. Instead, native English speakers pay more attention to the spectral qualities of F1 and F2 to distinguish tense-lax pairs.

An acoustical analysis measuring the F1 and F2 values of the English and Spanish phonemes /i, a, u/ by Mendez (1982) found no significant differences between the productions of /i/ and /a/. However, he did find a significant difference in the F2 values between English and Spanish /u/.

A comparison of the vowels /i, e, o, u/ by Bradlow (1995) found that the English tokens generally had higher F2 values. A larger F2 means that these vowels are articulated with a tongue position that is more forward in English than in Spanish. It also means that English /e/ and /i/ are more peripheral than their Spanish counterparts while at the same time making /o/ and /u/ more central. TABLE 1 illustrates the acoustic measurements for Spanish and English vowels. Comparing the results from Mendez (1982) with the measurements from Bradlow (1995) shows a discrepancy in the similarity of Spanish and English /u/. Mendez claims that there is a significant difference in the two, however the mean measurements of Spanish /u/ from Bradlow fall within the acoustic range of acceptable productions of English /u/ found by Bradlow's (1995) and Peterson & Barney's (1952) measurements.[4] If we follow Bradlow's measurements below, this overlap between English and Spanish /u/ may reveal instances where L1-L2 category

[4] The acoustic measurements of American English vowels collected by Peterson & Barney (1952) have been cited in numerous studies regarding speech perception (Cebrian, 2008; Rallo Fabroa & Romero, 2012; Mendez, 1982). These measurements are often included because they collected speech from 33 male speakers from many American dialects. It is considered to be representative of General American Speech. (Rallo Fabra & Romero, 2012).

assimilation will be more common. This may help determine where difficulties in discrimination of L2 category formation may arise.

Table 1
Mean formant values for English & Spanish vowels

	Spanish					English [CVC]			
	Bradlow		Mendez			Bradlow		Peterson & Barney	
	F1	F2	F1	F2		F1	F2	F1	F2
/i/	286	2147	350	2478	/i/	268	2393	270	2290
					/ɪ/	463	1995	390	1990
/e/	458	1814	--	--	/e/	430	2200	--	--
					/ɛ/	635	1796	530	1840
					/æ/	777	1738	660	1720
					/ʌ/	640	1354	640	1190
/a/	638	1353	756	1178	/ɑ/	780	1244	730	1090
					/ɔ/	620	1033	570	840
/o/	460	1019	--	--	/o/	482	1160	--	--
					/ʊ/	481	1331	440	1020
/u/	322	992	336	751	/u/	326	1238	300	870

This table presents a means of comparison between the average F1 and F2 values of English and Spanish from three previous studies: Bradlow (1995), Mendez (1982) and Peterson & Barney (1952).

1.3 APPROACHES

Much of L2 perception research is based on Vowel Assimilation (Escudero & Chládková, 2010), Discrimination tasks (Cebrian, 2006) or a combination of both (Cebrian, 2008; Flege & MacKay, 2004; Rallo Fabra & Romero, 2012). Cebrian et al. (2010) points out that using a variety of tasks to measure cross-linguistic distance will give us a, "more complete and reliable measure of crosslinguistic similarity."

Cross-language assimilation tasks form the basis for many L2 perception studies (Cebrain, 2008; Rallo Fabra, 2005; Rallo Fabra & Romero, 2012). In this type of task

participants classify L2 sounds in terms of their L1 and assign a goodness rating to the L2-L1 pairs. PAM-L2 uses the similarity relations established here to predict the relative difficulty that will occur in the discrimination of two L2 sounds.

Discrimination tasks are often used by researchers, in part, to see if language learners have established new L2 phonetic categories (Flege & MacKay, 2004; Rallo Fabra & Romero, 2012; Cebrian 2008). During this task two L2 sounds are presented to the participant and they must determine whether the two sounds are instances of the same sound or if they represent two different sounds. Since the establishment of new L2 categories increases language learners' sensitivity to between-category differences while decreasing sensitivity to within-category differences that can occur between speakers (ie. pitch, tone etc.), it is expected that language learners will have greater difficulty in discriminating the tokens of an L2 contrast if they do not have the necessary L2 categories formed (Flege, 1995).

1.4 PRESENT STUDY

The purpose of this investigation is to examine the perception of L2 English vowels by native Spanish speakers through the framework of PAM-L2. Many studies have examined the cross-linguistic similarities between the vowels of English and Spanish, but I found none that had done so using the PAM-L2. The findings from this investigation will add to the existing scholarship of L2 English speech perception by means of an avenue that has yet to be traversed. Moreover, this study will test the belief that the difficulty of discriminating between two L2 sounds can be predicted by analyzing L2-L1 vowel assimilation patterns alone.

As mentioned in section 1.3, many studies dealing with L2 speech perception and cross-linguistic similarity utilize a vowel assimilation task and a categorical discrimination task to assess L2 category formation. This study goes one step further and includes a forced identification task as well. The vowel identification task adds another dimension to the study by not simply having the participants determine if two sounds are *the same* or *different*, but by having them rely on the L2 categories they have established. These two tasks working in conjunction will hopefully allow us to define the contents of the L2 categories that the participants are found to have.

1.5 OVERVIEW

The remainder of this paper is divided into four sections. Section two describes the L2-L1 vowel assimilation task and serves as an introduction to the stimuli, participants, and gives a brief overview of its most important results. Sections three and four describe the discrimination and identification tasks, respectively, and offer a quick review the stimuli and participants from the first experiment, but focus mainly on the explanation and results of the discrimination and identification tasks. Section five is where we combine the results from all three activities into a cohesive, telling interpretation of native Spanish speakers' perception of English vowels.

2.0 EXPERIMENT 1 – VOWEL ASSIMILATION

The goal of this vowel assimilation task is to assess how native Spanish speakers perceive the relation between L2 English vowels and L1 Spanish vowels. The PAM-L2 suggests that predictions can be made about the level of discrimination difficulty of two L2 sounds by analyzing how each is categorized onto the L1 sound system. Therefore the patterns of categorization found here will provide the foundation for making and assessing the predictions of the ten English vowel contrasts that will be under investigation in the AX categorical discrimination task (Experiment 2).

2.1 METHOD

2.1.1 Stimuli

The ten English vowels under investigation (/i, ɪ, e^{ɪ}, ɛ, æ, ɑ, ɔ, o, ʊ, u/) were presented in CVC[5] environments that corresponded with entries on the list of the 2,000 most commonly used English words, according to the British National Corpus (BNC). Real,

[5] A full list of the words used in this study can be found in Appendix A

frequent words were chosen to maximize the chances that the participants would have mental representations of each token.

When dealing with cross-linguistic comparisons and perception of L2 vowels, one must remember that stress often plays an important role in determining vowel quality. In many languages, like German, Catalan, and English when a vowel is located in an unstressed syllable it goes through a process of reduction or neutralization. Spanish differs in this regard because it does not go through this process of reduction while unstressed English vowels become the more centralized [ə] or [ɨ] (Flemming & Johnson, 2007). The centralization of English vowels can be heard, for example, in words like *below* [bəˈloʊ] and *dishes* [ˈdɪʃɨz]. However, for the purposes of the current investigation, vowel reduction will not be an issue since only vowels appearing in stressed positions will be studied.

Because surrounding consonants have been shown to affect the perception of vowels (Bohn & Steinlen, 2003), the bVC and hVC contexts were used here to minimize this influence. Levy (2009) found that L1 English speakers mapped French vowels onto their native sound system more consistently when a bilabial consonant preceded the vowel than when an alveolar consonant came first. The hVC environment, in turn, was chosen because it diminishes C to V coarticulation (Cebrian, 2006). Both bVC and hVC environments have been used in multiple studies focused on L2 vowel perception (Mayr & Escudero, 2010; Flege & MacKay, 2004; Cebrian, 2008) and therefore can be compared more easily to the data collected here.

The English vowels were first placed into the bVt context. If this construction did not produce a word following the BNC frequency criterion above, the voicing of the initial consonant was kept the same, but the place of articulation changed from bilabial to

alveolar, creating dVt (e.g. *date* and *dot*). There was one instance in which neither the bVt nor dVt context produced a word on the BNC list and therefore the /t/ in the coda was changed to /k/ to form *book*.

The English vowels were also presented in the hVt environment using the same criterion from the BNC. When this criterion was not met, the vowel was placed in a kVt context. There was one instance where neither of the contexts produced a viable word. In this case the final /t/ remained alveolar but became voiced resulting in *head*.

Four native English speakers, who self-identified as users of Standard American English, recorded the full list of words directly onto the lead researcher's PowerBook using a USB microphone in the recording studio of the Robert Henderson Language Media Center at the University of Pittsburgh. To minimize any chances of getting an order effect, every speaker read each word aloud three times as they appeared in a random order on the computer. The words from two speakers, one male from Flint, Michigan, and one female from Buffalo, New York were chosen because of the clarity of their speech and the presence of the /ɔ/-/o/ distinction, which was not always present in the other two speakers. In the chance that the vowel pronunciation from the principal two speakers was heard as atypical by the lead investigator, the production of the same token from the other native English speaker of the same gender was used.[6]

[6] Of all the words produced by females in this study, 88% were done by the woman from Buffalo, New York and 12% were done by a woman from Nashville, Tennessee. For the males, 85% were produced by the man from Flint, Michigan and 15% were produced by a man from Columbus, Ohio.

2.1.2 Task

Before the vowel assimilation task began, the directions were presented on the computer screen that the participants could read at their own pace. After they read the instructions, there was a brief practice session consisting of five trials. The practice session was included to make the participant comfortable with the activity and reduce the chances of confusion before the actual exercise began. At the end of the practice session the participants could continue to the main part of the activity or go through the practice session again if they felt more training was needed. No participant repeated the practice.

The auditory stimuli were randomly presented through headphones in the Phonetics Computer Lab on campus. The first time an English word was presented, the participants classified the vowel into the Spanish sound system by pressing a button on the response pad (MODEL: RB-830) that corresponded with the Spanish vowel highlighted within a word on the computer screen, as displayed in the screen shot below:

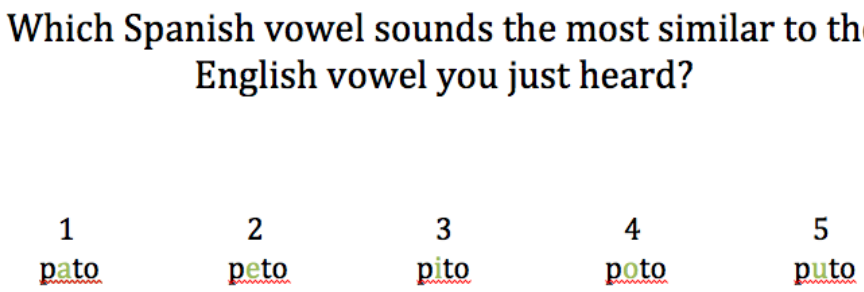

Figure 2: First screen shot of Vowel Assimilation Task instructions.

After categorizing the L2 vowel, the participants heard the same recording again and rated its similarity to the vowel they just selected using a Likert scale from 1 (not similar) to 6 (very similar) (Flege & McKay 2004).

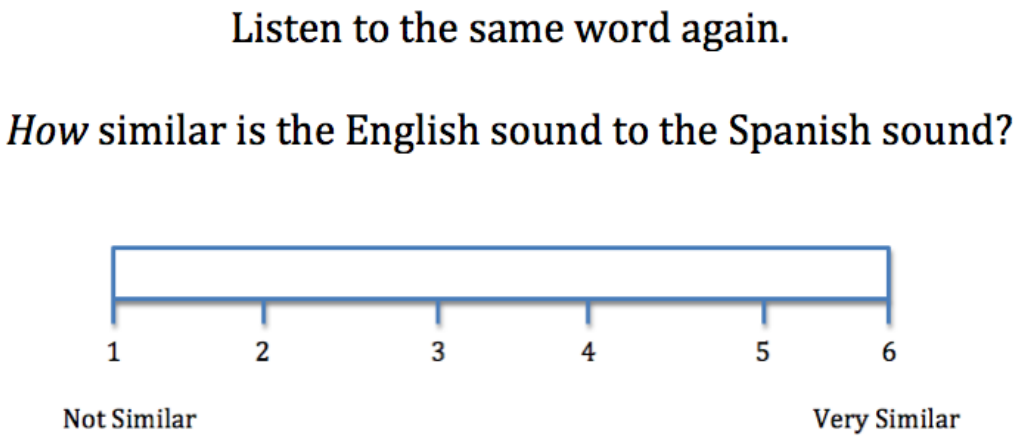

Figure 3: Second screen shot of Vowel Assimilation Task instructions.

The participants heard each word from the bVC and hVC contexts four times: twice by a male voice and twice by a female voice. Each vowel was represented by multiple utterances; the participants did not hear a single utterance more than once within a single task. This resulted in each vowel being mapped onto the Spanish vowel system 96 times (12 participants x 8 presentations of each vowel).

2.1.3 Listeners

Twelve native Spanish speakers (5 male, 7 female) completed these tasks individually in the Phonetics Lab of the University of Pittsburgh. The participants were from various

countries (3 Bolivia, 1 Costa Rica, 1 Colombia, 1 Ecuador, 3 Mexico, 1 Peru, 1 Nicaragua, 1 Uruguay, 1 Spain), ranged in age from 26-41 (M=31.4 years), had been studying English from 2-25 years (M=14.7 years), and had been in the US from 7months-10 years (M=4.2 years). Each participant was a graduate student in the Hispanic Languages and Literature Department of the same university and at one time or another passed an English proficiency exam administered by the university before they were given clearance to work as Graduate Teaching Assistants. On a language history questionnaire[7] that was filled out prior to collecting any perception data, all indicated they had normal hearing and that they did not attend an English-speaking primary or secondary school. While some had experience with other languages, English was always the second most fluent language the participants spoke, after Spanish.

2.2 RESULTS

Table 2 below presents the mean percentage of times the ten English vowels under investigation were classified as each one of the five Spanish vowels. The bolded percentages indicate the modal assimilation of each English vowel. As expected from Bradlow (1995), we see English vowels being assimilated to multiple Spanish categories at varying frequencies and with different goodness-of-fit scores. To start, English /i/ and /æ/ had the highest rates of assimilation (93%) to their respective Spanish category, /i/ and /a/. Additionally, they also had the second and third highest goodness-of-fit ratings suggesting that native Spanish speakers

[7] Full questionnaire found in Appendix B.

perceived these two English sounds to be very similar to their Spanish counterparts. However, they were not the only English vowels to be mapped on to Spanish /i/ and /a/.

Table 2
L2 Vowel Assimilation

English Vowel Stimuli	Assimilation to Spanish Category				
	/i/	/e/	/a/	/o/	/u/
/i/	**93%** (4.55)	7% (2.71)	---	---	---
/ɪ/	**75%** (3.93)	24% (3.87)	---	---	---
/eᴵ/	7% (2.14)	**84%** (3.19)	8% (3.5)	---	---
/ɛ/	---	**74%** (3.91)	22% (3.86)	---	---
/æ/	---	6% (2.67)	**93%** (4.14)	---	---
/ɑ/	---	---	**74%** (3.84)	24% (3.83)	---
/ɔ/	---	---	35% (3.36)	**62%** (3.72)	---
/o/	---	---	---	**89%** (3.46)	11% (2.8)
/ʊ/	---	---	---	34% (3.64)	**65%** (4.11)
/u/	---	---	---	10% (3.33)	**85%** (4.72)

Percent assimilation of English vowels into the Spanish sound system with goodness-of-fit rating in parentheses. Bold percentages represent the modal classification for each English vowel. Percentages less than 4% (ie. three responses out of 96) were omitted.

The Spanish categories /i/ and /a/ are prime examples of how multiple L2 sounds can assimilate onto a single L1 category and how different assimilation patterns lead to different predictions by the PAM-L2. For example, English /i/ and /ɪ/ were frequently assimilated to the Spanish category /i/, at rates of 93% and 75%, respectively. These high rates of assimilation, couples with high goodness-of-git scores, suggest a strong similarity between these two English vowels and one Spanish vowel. Since both are perceived to be relatively similar to the same L1 category, the /i-ɪ/ distinction may be difficult for the participants to hear. The only other L2 vowel to be assimilated onto Spanish /i/ was English /eᴵ/, but this was done infrequently (7%) and with a low goodness-of-fit rating of 2.14 out of 6.0.

There is a similar relationship between English /æ/ and /ɑ/ and Spanish /a/. The two English vowels are categorized as Spanish /a/ with almost the same frequency as the example

above, 93% and 74%. However, in addition to these assimilations, English /ɛ/ and /ɔ/ were also assimilated to Spanish /a/ 22% and 35% of the time.

While certain vowels, like English /i/ and /æ/ are perceived to be very similar to the participants' established Spanish categories, not all L2 vowels are as easy to assimilate. The English vowels /ɔ/ and /ʊ/ were the least readily assimilated to a Spanish category (62% and 65%, respectively). Since perceived similarity is at the cornerstone of PAM-L2's predictions, we may see participants perform differently with these two vowels than with the more assimilated ones.

Bradlow (1995) suggests that the complexity of coordinating L2 and L1 categories is due to the large difference in the languages' vowel inventories. As mentioned earlier, English has over twice the number of vowels as Spanish so it is inevitable that we see more than one English vowel assimilating to a single Spanish category. The elaborate mapping is further complicated by findings that the perceived similarity of an L2 sound does not always coincide with the most acoustically comparable L1 sound (Flege, 1991; Morrison, 2009). Thus Cebrian (2008) states that the incongruity between perceived similarity and acoustic similarity may necessitate a focus on more than just F1 and F2 when measuring cross-linguistic similarity.

Table 3

Assimilation patterns of English vowels to Spanish vowels based on PAM-L2

Predicted Difficulty	English Vowel Contrast	Percent Assim. to Spanish Category	Perceptual Assim. Pattern
Difficult	/i-ɪ/	/i/ → /i/ (93%) /ɪ/ → /i/ (75%)	Single-Category
	/eᴵ-ɛ/	/eᴵ/ → /e/ (84%) /ɛ/ → /e/ (74%)	Single-Category
	/æ-ɑ/	/æ/ → /a/ (93%) /ɑ/ → /a/ (74%)	Single-Category
Relatively Easy	/æ-ɔ/	/æ/ → /a/ (93%) /ɔ/ →/a/ (35%)	Category-Goodness
	/ɑ-ɔ/	/ɑ/ → /a/ (74%) /ɔ/ → /a/ (35%)	Category-Goodness
	/ɔ-ʊ/	/ɔ/ → /o/ (62%) /ʊ/ → /o/ (34%)	Category-Goodness
	/o-ʊ/	/o/ → /o/ (89%) /ʊ/ → /o/ (34%)	Category-Goodness
	/ʊ-u/	/ʊ/ → /u/ (65%) /u/ → /u/ (85%)	Category-Goodness
Easy	/ɪ-eᴵ/	/ɪ/ → /i/ (75%) /eᴵ/ → /e/ (84%)	Two-Category
	/ɛ-æ/	/ɛ/ → /e/ (74%) /æ/ → /a/ (93%)	Two-Category

Table designed after Rallo Fabra & Romero (2012) pg. 6. Following Rallo Fabra (2005), 85% assimilation to an L1 vowel is *consistent;* 75% is *quite consistent.* The latter percentage will act as a guide for the lower boundary when determining if an L2-L1 assimilation is a *good fit*.

From this seemingly complex system of L2→L1 vowel assimilation, the predictions from the PAM-L2 emerge. As shown in Table 3 above, the assimilation patterns of the L2 vowel contrasts for this investigation have been determined qualitatively, regarding the percentage of instances an English vowel was assimilated to a Spanish category, as has been done in many previous investigations (Rallo Fabra & Romero, 2012; Escudero & Chladkova, 2010; Cebrian, 2008;). In order to determine what percent assimilation constitutes a *good fit* for an L2 vowel in the L1 sound system, I refer to two statements made by Rallo Fabra (2005) claiming that an L2 vowel is assimilated to an L1 vowel *consistently* when it is classified to the same category 85%

of the time and *quite consistently* when it is classified to one L1 vowel 75% of the time. The latter of these two ratios will act as a guide when determining the goodness-of-fit based on percentages. For instance, as shown in Table 3, English /i/ and /ɪ/ are both frequently assimilated onto the same Spanish category /i/, thereby fulfilling the requirements of the *single-category assimilation* pattern. PAM-L2 predicts that these native Spanish speakers will have a difficult time discriminating between these two sounds. English /æ/ and /ɔ/ are both assimilated onto Spanish /a/ but, according to the criterion put forth by Rallo Fabra (2005), they are done so at different rates (93% and 35%, respectively). Because of this variation, the /æ-ɔ/ contrast forms part of the *category-goodness assimilation* pattern and is predicted to be easier to perceive than the *single-category* pattern. Finally, one of the easiest contrasts to perceive, according to the PAM-L2's predictions, will be /e^{I}-ɪ/ because each L2 vowel is reliably assimilated onto a distinct L1 category; English /e^{I}/→ Spanish /e/ (75%) and English /ɪ/→ Spanish /i/ (84%). This contrasts falls under the *two-category assimilation* pattern.

2.3 CONCLUSION

In order to quantify the perceptual similarity of English and Spanish vowels, native Spanish speakers completed a vowel assimilation task by categorizing English vowels into their L1 sound system. As referenced in Bradlow (1995), the categorization of L2 sounds onto L1 sounds can result in a complex web of similarities and differences. However, by examining the relationship between L2 and L1 vowel sounds through the framework of the PAM-L2 we can make predictions about the difficulty that L1 Spanish speakers will have when discriminating certain L2 vowel contrasts, which are summarized in Table 3. In the next section we will explore the discrimination results of the ten English vowel contrasts to see how well they reflect the outcomes predicted by PAM-L2 in Table 3.

3.0 EXPERIMENT 2 – CATEGORICAL DISCRIMINATION

As stated by the PAM-L2 in the previous section, not all L2 vowel contrasts will be discriminated equally well; the level of discrimination difficulty is determined by how each vowel of a contrast is categorized onto the sound system of the L1. The purpose of the AX categorical discrimination task is to assess the predictions made by the PAM-L2 and to determine which English vowel contrasts are easy and difficult for L1 Spanish speakers to perceive. By knowing which L2 contrasts are difficult to discriminate for native Spanish speakers, we get an idea of which L2 phonetic categories have not been fully established yet in their mental representation of the English language (Logan & Pruitt, 1995).

3.1 METHOD

3.1.1 Stimuli

The stimuli presented to the participants in this task were the same bVC and dVC stimuli from the vowel assimilation task (experiment 1). The hVC and kVC stimuli were not used in this portion of the experiment.

3.1.2 Task

Once again, the testing for this task was done in the phonetics lab at the University of Pittsburgh. The auditory stimuli were presented through headphones using the same recording as in the previous task. The participants were told to pay special attention to the vowels and to press the green button on the response pad (MODEL: RB-830) if the words contained the same vowel sound and the red button if the words contained two different vowel sounds. During the activity no feedback was given, but there were five extra trials presented for practice before data was collected. Each contrast was preceded by 800 ms of silence and there were 500 ms of silence between the individual utterances of the contrast.

A total of 200 discrimination contrasts were randomly presented to the participants. Each of the ten English vowels was presented in a contrast with each of English vowels under investigation (10 vowels x 10 vowels = 100 vowel contrasts). To prevent any order effects, each contrast was presented in the opposite sequence as well (ex. Male *bat* – Female *bought*; Female *bought* – Male *bat*) [100 vowel contrasts x 2 orders = 200 vowel contrasts]. Only the bVC and dVC words were used in this task.

The fact that the words in question were spoken by two different speakers required the participants to disregard any within-category variation between speakers while remaining attentive to the characteristics of each vowel that indicate a change in category. If the participants have formed a new phonetic category for any particular vowel sound there will be a decrease in sensitivity to within-category differences and an increase in their sensitivity to between category differences (Flege & MacKay, 2004).

3.1.3 Listeners

All twelve participants from the previous activity also participated in the AX Discrimination task. While participant 6 was doing this activity, there was an issue with the computer and the program unexpectedly quit. This participant's answers stopped recording after the 125th contrast. Additionally, there were a few times when other participants accidentally pressed the wrong button. For these reasons there are unequal totals for each comparison. At most, a vowel contrast was discriminated a total of 24 times (2 presentations x 12 participants).

3.2 RESULTS

In the subsections that follow, the L2 contrasts are displayed in individual charts grouped by the assimilation patterns determined by the PAM-L2 framework expressed in section 1.1 and in Table 3. A full table of all the discrimination patterns appears in Appendix C.

3.2.1 Single-Category Assimilations

Table 4
Discrimination of *single-category* contrasts

Contrast	% perceived as "same"
/i-ɪ/	74%
/ɪ-i/	41%
/i-i/	95%
/ɪ-ɪ/	91%

Contrast	% perceived as "same"
/eˈ-ɛ/	13%
/ɛ-eˈ/	13%
/eˈ-eˈ/	100%
/ɛ-ɛ/	96%

Contrast	% perceived as "same"
/æ-ɑ/	52%
/ɑ-æ/	39%
/æ-æ/	91%
/ɑ-ɑ/	82%

The charts above display (in percent) the frequency with which the tokens of each *single-category* contrast were perceived as "the same".

Tables A, B, and C present the frequency that two tokens from each English contrast were perceived as *the same*. It appears that the native Spanish speakers disregard within-category differences reliably well. Contrasts containing two tokens from the same phonetic category (e.g. /i-i/, /æ-æ/ etc.) are consistently perceived as *the same* with accuracy ranging from 82% (/ɑ-ɑ/) to 100% (/$e^{ɪ}$-$e^{ɪ}$/). However simply being able to label two sounds as *the same* doesn't mean one has established an accurate mental representation of these sounds. Before we claim that new phonetic categories for L2 English vowels have been created we also need to analyze the participants' ability to discriminate between sounds that belong to two distinct categories.

When we examine the NS speakers' ability to perceive between-category differences we see that the three *single-category* contrasts displayed above are not perceived with the same accuracy. In addition to accurately perceiving same-category contrasts in Table 4C, the native Spanish speakers were also able to perceive the between-category differences of /$e^{ɪ}$/ and /ɛ/ at a rate of 87%, regardless of the order they were presented in (/ɛ-$e^{ɪ}$/-vs-/$e^{ɪ}$-ɛ/).

On the other hand, tables 4A and 4B, /i-ɪ/ and /æ-ɑ/, illustrate how accurate within-category perception does not necessarily transfer to accurate between-category discrimination. This is particularly salient in the /i-ɪ/ contrast where NS speakers misidentified the vowels in *beat* and *bit* as the same in 74% of all cases. The same group of listeners also perceived the /æ-ɑ/ contrast as containing tokens from the same English category 52% of the time. Even though the participants' accuracy increased when the tokens of the contrasts were presented in reverse order, they were able to perform only slightly better than chance, which was set at 50%.

In response to previous studies that found contrasts were easier to decipher if presented in one order over another, Polka& Bohn (2003) proposed that infants show a bias toward vowels that are in the periphery of the F1/F2 space and that the more peripheral vowel in a contrast acts

as “an anchor.” When this anchor appears as the second token of a contrast it will be easier for infants to discriminate. In 2011, Polka and Bohn expanded upon their previous study with infants and found that adults also experience this directional asymmetry with nonnative vowel contrasts and experience similar perceptual biases for vowel sounds at the F1/F2 extremes.

Within the Natural Referent Vowel (NRV) framework created by Polka & Bohn (2011) is the reiteration that directional asymmetries exist in the perception of vowel contrasts. More specifically, it states that participants will have a more accurate perception of a vowel contrast when the peripheral vowel is presented after the more central vowel. Using the NRV framework, we can accurately explain why the NS speakers perceived a difference between /ɪ-i/ and /ɑ-æ/ better than when the order was reversed, /i-ɪ/ and /æ-ɑ/. However, the NRV is of little help regarding the symmetry found in the /e^{ɪ}-ɛ/ and /ɛ-e^{ɪ}/ contrasts where each one was discriminated with the same amount of accuracy, 87%.

It is important to keep in mind that even though English /e^{ɪ}/ and /ɛ/ were easily discriminated by L1 Spanish speakers, this does not constitute an established L2 category. Instead it suggests that the cues Spanish speakers use to discriminate /e^{ɪ}/ and /ɛ/ do not overlap and lead to confusion. Moreover it is still possible for either of these two English categories to be confused with a different English category. To investigate this further we would have to take a look at other contrasts that contain /e^{ɪ}/ and /ɛ/.

3.2.2 Category-Goodness Assimilation Pattern

L2 contrasts where both vowels are assimilated onto the same L1 category, but at different rates, are described as being part of the category-goodness assimilation pattern. In this kind of contrast, one token of the pair will be perceived as a more prototypical example of the L1

category than the other. PAM-L2 predicts that this difference in goodness will result in two sounds that are relatively easy to contrast.

Table 5
Discrimination of *category-goodness* contrasts

Contrast	% perceived as "same"
/æ-ɔ/	39%
/ɔ-æ/	35%
/æ-æ/	91%
/ɔ-ɔ/	86%

Contrast	% perceived as "same"
/ɑ-ɔ/	61%
/ɔ-ɑ/	59%
/ɑ-ɑ/	82%
/ɔ-ɔ/	86%

Contrast	% perceived as "same"
/o-ɔ/	42%
/ɔ-o/	33%
/o-o/	86%
/ɔ-ɔ/	86%

Contrast	% perceived as "same"
/o-ʊ/	25%
/ʊ-o/	33%
/o-o/	86%
/ʊ-ʊ/	95%

Contrast	% perceived as "same"
/ʊ-u/	67%
/u-ʊ/	50%
/ʊ-ʊ/	95%
/u-u/	100%

The charts above display (in percent) the frequency with which the tokens of each *category-goodness* contrast were perceived as "the same".

As with the contrasts from the *single-category* assimilation pattern, the native Spanish speakers were able to consistently recognize when the two tokens of a contrast contained the same vowel sound. However, as we saw in the section above, it is necessary to look at how well they discriminate sounds belonging to two English categories. Here we expect to see higher rates of between-category discrimination than in the last section because the predicted level of discrimination difficulty is not as high, but at the same time we do not expect to see levels of discrimination that would indicate high levels of consistent distinguishability.

We notice this outcome in three of the five English contrasts: /æ-ɔ/, /o-ɔ/, and /o-ʊ/. In these contrasts, the rate of correct discrimination is above chance (50%), regardless of the order in which the tokens are presented and below what would be considered consistent correct

discrimination with the exception of perhaps one contrast, /ɒ-ʊ/, which was discriminated correctly in 75% of the cases.

In the remaining two contrasts, /ɑ-ɔ/ and /ʊ-u/, displayed in tables 5B and 5E, we see much lower rates of correct discrimination than expected. /ɑ-ɔ/ and /ɔ-ɑ/ are heard as tokens of the same category 61% and 59%, respectively. We see similar numbers with /ʊ/ and /u/ which were perceived as members of a singular English category 66% and 50% of the time. Such poor between-category discrimination suggests that the participants will also have a difficult time distinguishing between the two in the forced identification task that follows.

3.2.3 Two-Category Assimilation Pattern

According to PAM-L2, the contrasts below should not pose any problems in discrimination for native Spanish speakers because the tokens within each contrast were assimilated onto distinct L1 vowels. The following vowel contrasts were chosen by the investigator for two reasons: first, because of the proximity of the vowel categories to each other in the English sound system, and second, because of the consistency with which the native Spanish speakers assimilated each sound of the contrast to the corresponding L1 category.

Table 6
Discrimination of *two-category* contrasts

Contrast	% perceived as "same"
/ɪ-eᴵ/	22%
/eᴵ-ɪ/	9%
/ɪ-ɪ/	91%
/eᴵ-eᴵ/	100%

Contrast	% perceived as "same"
/æ-ɛ/	87%
/ɛ-æ/	75%
/æ-æ/	91%
/ɛ-ɛ/	96%

The charts above display (in percent) the frequency with which the tokens of each *double-category* contrast were perceived as "the same".

/ɪ/ and /eᴵ/ are neighboring sounds in the English sound system and they were assimilated onto neighboring categories in the Spanish sound system at similar rates: English /ɪ/ assimilated to Spanish /i/ at a rate of 77% and English /eᴵ/ assimilated to Spanish /e/ at a rate of 81%. The participants perceived the differences between these two English categories at consistently high levels, suggesting that the cues used by native Spanish speakers to discriminate these two sounds did not overlap. The difference in accurate discrimination due to order effects can be explained by the NRV.

Even though the vowels /ɛ/ and /æ/ were predicted to be easily distinguishable by PAM-L2, they were the least accurately discriminated of all the contrasts investigated in this study. /ɛ/ and /æ/ were perceived as the same sound at the remarkable rates of 87% and 75%. Once again the NRV correctly predicts that the /ɛ-æ/ contrast will be easier to discriminate than /æ-ɛ/ based on how the tokens within each contrast are presented.

3.3 CONCLUSION

In the AX categorical discrimination task ten L2 English vowel contrasts were separated into one of three assimilation patterns spelled out in section 1.1. The participants had to decide if the tokens of a contrast belonged to the same category or different categories. PAM-L2 predicts different levels of discrimination difficulty based on how each member of the contrast assimilates onto the L1. However, what we saw here is that any L2 contrast can be discriminated well or poorly, regardless of its assimilation pattern. For example, out of the three pairs described as Single-Category assimilation, one was easy for the NS to discriminate, one was difficult, and the other was intermediate. Of the five contrasts within the Category-Goodness assimilation pattern, no contrast was easy to discriminate, two contrasts were discriminated poorly and three were discriminated slightly better than chance. Finally, of the two contrasts analyzed in the Two-Category assimilation pattern, one was easy to discriminate and the other was difficult. The next step is to see if the same problems areas in discrimination are present in the forced identification task (experiment 3).

4.0 EXPERIMENT 3 – FORCED IDENTIFICATION

While the discrimination task (experiment 2) tested the participants' ability to detect if two members of a contrast were the same or different, the forced identification task (experiment 3) is more abstract and requires the participants to rely heavily on their mental representations of L2 vowels to make categorizations based on the characteristics of each individual stimulus item (Logan & Pruitt, 1995).

4.1 METHOD

4.1.1 Stimuli

The stimuli presented in this task were the same words used in experiment 1 produced by the same native English speakers.

4.1.2 Task

Prior to the start of this task the subjects participated in a practice activity to verify that they had a mental representation of certain words that would be used as a reference in the identification task. For the first practice activity, five pictures were presented on the

computer screen; each picture was of a word that contained one of the five English front vowels: *keys* [kʰiz], *pig* [pʰɪg], *cake* [kʰeˈk], *pen* [pʰɛn], and *can* [kʰæn]. The names of the pictures were produced by a native speaker of standard American English and upon hearing the name of the picture the participants were instructed to press the corresponding button on the response pad. For example, if the native English speaker said *pig*, the participant would have to press the button that corresponded with the picture of a pig on the computer screen. Feedback was provided on the computer screen and indicated a right or wrong response. If the wrong button was pushed, a *try again* icon appeared on the screen and the same sound file was played again. A correct response was required before the next word could be heard. The participants must have responded correctly to each picture-word combination twice before the practice activity ended. At the end of this first section the subjects had the opportunity to repeat it if they did not feel comfortable with the words or the pictures. No one repeated this portion of the activity.

Upon successful completion of the practice task, the participants were given instructions for the identification activity. (A screen shot of the instructions for this activity can be seen in Figure 4.) They were instructed to match the vowel sound of the word they heard to the picture on the computer screen that contained the same vowel sound by pressing the corresponding button on the response pad. For example, if they heard the word *bat*, they would have to press the button that corresponded with the picture *can*, because both contain the vowel [æ]. There was a short practice of five tokens that was not recorded. After the practice, the listeners had the option to repeat the practice if they felt uncomfortable or did not understand the instructions. None of the participants repeated the practice. In the first portion of this task the participants

only heard English front vowels and were only given the option of selecting from words containing English front vowels.

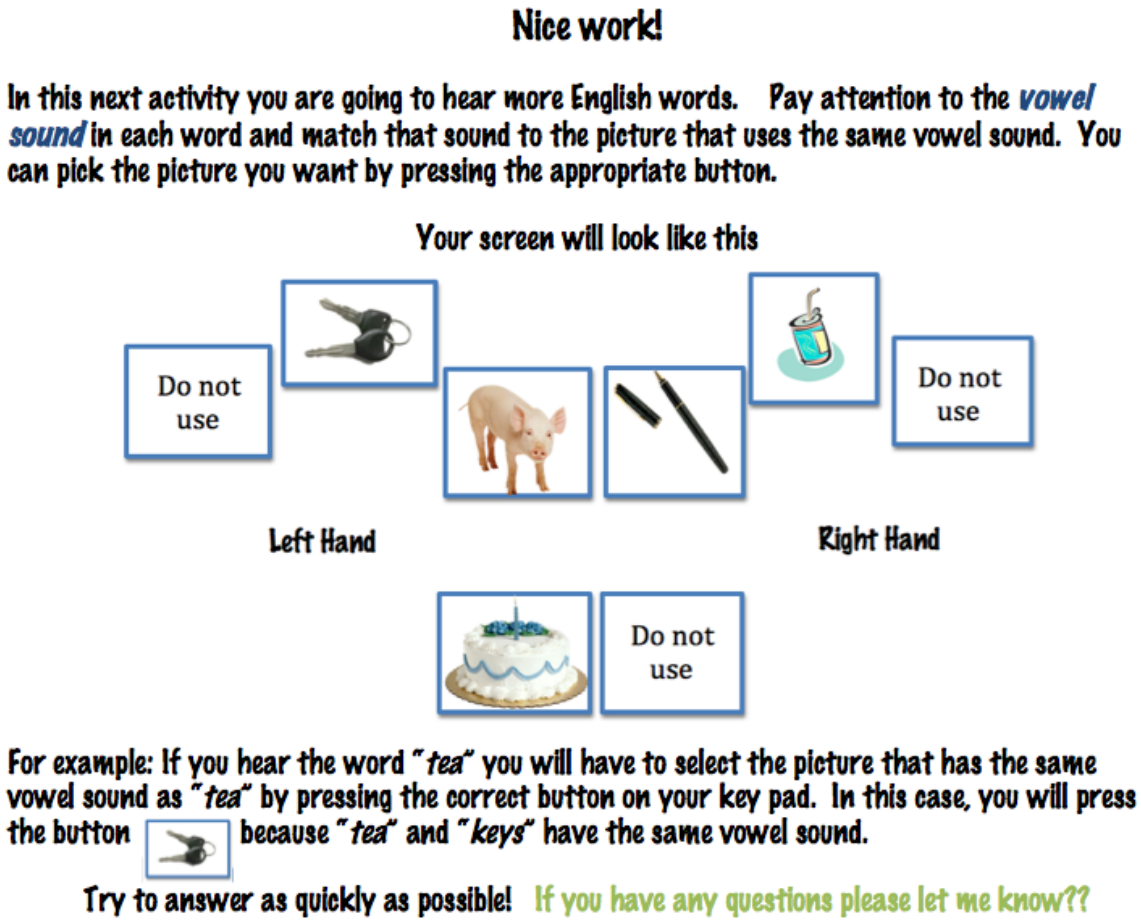

Figure 4: Instructions for Forced Identification Task. The instructions presented to the participants after the practice session.

After the participants completed the task containing the English front vowels, they repeated the word-vowel verification task, but this time with back vowels. The reference words for the back vowels that were depicted on the screen were as follows: *top* [t^{h}ɑp], *off* [ɔf], *rose* [ro^{ʊ}z], *foot* [fʊt], and *soup* [sup]. Once they successfully finished, they were shown the instructions for the forced identification task one more time and they did a practice run of the activity with five tokens.

The participants heard each vowel eight times. The vowels were presented using the same male and female speakers from the previous activities. Both speakers were recorded saying the same bVC/dVC and hVC/kVC contexts as before. There were a total of 80 tokens in this task (2 speakers x 10 vowels x 2 contexts x 2 repetitions). Therefore each vowel was identified by a native Spanish speaker 96 times (8 tokens of each vowel x 12 participants).

4.2 RESULTS

Tables 7 and 8 show how the native Spanish speakers identified English vowel sounds. Once again, the results section is divided into three sections corresponding to the assimilation patterns used to make predictions with PAM-L2. Tables for individual contrasts are presented at the beginning of each section. Results for individual contrasts will be contrasted with those of Tables 7 and 8 to get a more general view of identification patterns.

Table 7
Forced identification of English front vowels

English token presented	English token perceived as					
		/i/	/ɪ/	/eᴵ/	/ɛ/	/æ/
	/i/	44%	**54%**	1%	1%	0%
	/ɪ/	12%	**71%**	5%	11%	2%
	/eᴵ/	2%	2%	**89%**	6%	0%
	/ɛ/	1%	6%	7%	**57%**	28%
	/æ/	0%	1%	4%	5%	**89%**

This table presents the identification patterns of English vowels by L1 Spanish speakers. Bolded percentages indicate modal identification

Table 8
Forced identification of English back vowels

English token presented	English token perceived as					
		/ɑ/	/ɔ/	/o/	/ʊ/	/u/
	/ɑ/	**63%**	18%	0%	7%	15%
	/ɔ/	**54%**	23%	1%	9%	15%
	/o/	4%	10%	**45%**	18%	19%
	/ʊ/	3%	7%	4%	**50%**	30%
	/u/	0%	4%	3%	**50%**	43%

This table presents the identification patterns of English vowels by L1 Spanish speakers. Bolded percentages indicate modal identification

4.2.1 Single-Category Assimilation

Table 9
Single-category two-token identification chart

a.

Token presented	Perceived as /i/	Perceived as /ɪ/
/i/	44%	54%
/ɪ/	12%	71%

b.

Token presented	Perceived as /eᴵ/	Perceived as /ɛ/
/eᴵ/	89%	6%
/ɛ/	7%	57%

c.

Token presented	Perceived as /æ/	Perceived as /ɑ/
/æ/	89%	na
/ɑ/	na	63%

Each chart presents the rates of identification (in percent) for the contrasts predicted to fall into PAM-L2's *single-category* assimilation pattern.

Just as we saw the L1 Spanish speakers have difficulty discriminating between instances of /i/ and /ɪ/, we continue to see problems of perception in the identification task. In this contrast, words containing /i/ were correctly identified as having /i/ very inconsistently; only 44% of the time. In fact, English /i/ was more often misidentified as a member of the English category /ɪ/. However, this confusion seems to be somewhat one-sided, because /ɪ/ was accurately identified 71% of the time and only rarely mistaken for /i/ (12%).

In addition to seeing a high rate of identification for /eᴵ/ (89%) in table 9b, we also see that there is minimal misidentification as the other token of the contrast. /eᴵ/ is rarely labeled as /ɛ/ and the reverse is also true. Even though there is little confusion between these two sounds, this doesn't mean that the native Spanish speakers have already established accurate L2 categories. We must also compare the tokens of this contrast to other English vowels; what we find is that /ɛ/ is misidentified as /æ/ in a little over a quarter of all cases (28%). This trend will be described in further detail in the discussion section (section 5).

Unfortunately, the identification task is void of any information regarding the relationship between the next two contrasts, /æ-ɑ/ and /æ-ɔ/, from the tables 9c and 10a because

the tokens of each contrast span the front-back paradigm. For example, since /ɑ/ was never presented as a possible label for words containing /æ/ there was never any chance for the two sounds to be confused.

4.2.2 Category-Goodness Assimilation

Table 10
Category-goodness two-token identification chart

a.

Tokens presented \ Perceived as	/æ/	/ɔ/
/æ/	89%	na
/ɔ/	na	23%

b.

Tokens presented \ Perceived as	/ɑ/	/ɔ/
/ɑ/	63%	18%
/ɔ/	54%	23%

c.

Token presented \ Perceived as	/ɔ/	/o/
/ɔ/	23%	1%
/o/	10%	45%

d.

Token presented \ Perceived as	/o/	/ʊ/
/o/	45%	18%
/ʊ/	4%	50%

e.

Token presented \ Perceived as	/ʊ/	/u/
/ʊ/	50%	30%
/u/	50%	43%

Each chart presents the rates of identification (in percent) for the contrasts predicted to fall into PAM-L2's *category-goodness* assimilation pattern.

When we look at the /ɑ-ɔ/ contrast (table 10b) we see that when presented with words that contain either an /ɑ/ or /ɔ/ native Spanish speakers identify both as /ɑ/ well above chance (chance = 20%). In fact, instances of /ɔ/ are over twice as likely to be mislabeled as /ɑ/ than correctly identified as /ɔ/. To a lesser extent, we see a similar situation arise in the identification pattern /ʊ/ and /u/ (table 10e). /u/ is more often identified as /ʊ/ that /u/ by the participants of

this study, although here we see a more even distribution of misidentifications suggesting an interchangeability of these two L2 categories.

In tables 10c and 10d we see that there is not much confusion between /o/ and the other members of the contrast, /ɔ/ or /ʊ/. However, at the same time, there isn't much correct identification for /o/ either, just 45%. We can attribute low identification rates for /ɔ/ and /ʊ/ to the fact that they are often labeled as /ɑ/ and /u/, respectively, but /o/ is not consistently identified as any other English category (the closest would be /u/ at 19%, followed by /ʊ/ at 18%).

4.2.3 Two-Category Assimilation

Table 11
Two-category two-token identification chart

a.

Token presented	Perceived as /ɪ/	Perceived as /eᴵ/
/ɪ/	71%	5%
/eᴵ/	2%	89%

b.

Presented	Perceived as /ɛ/	Perceived as /æ/
/ɛ/	57%	28%
/æ/	5%	89%

Each chart presents the rates of identification (in percent) for the contrasts predicted to fall into PAM-L2's double*-category* assimilation pattern.

The two contrasts represented under the same *Two-Category* Assimilation Pattern illustrate two different identification patterns. In table 11a above, we see that /ɪ/ and /eᴵ/ were often identified correctly and that there was little cross-misidentification. However, in table 11b, we see that while /æ/ is correctly identified at a high rate (89%), /ɛ/ is not. Moreover, /ɛ/ is identified as /æ/ in 28% of all instances.

4.3 CONCLUSION

In the forced identification task (experiment 3) participants were asked to label vowel sounds they heard by selecting a picture on the computer screen that contained the same sound. Tables representing the same ten L2 English contrasts used in the discrimination task (experiment 2) were created and placed in the same groups based on the assimilation patterns in experiment 1. This time however, each table presented the frequency of correct identification and the frequency with which each token was misidentified as the other token in the table. Just as we saw in the discrimination task (experiment 2), patterns of identification cannot be adequately predicted by simply relying on L2-L1 vowel assimilation.

5.0 DISCUSSION

Vowel Assimilation Discussion

The results from the vowel assimilation activity (experiment 1) give further support to the claim by Bradlow (1995) that categorizing English vowels onto the Spanish sound system is intricate and complex. Due to the large difference between the number of vowels contained within each language's inventory (English, 10 and Spanish, 5), we see English vowels being assimilated onto Spanish vowels at varying frequencies and degrees of goodness. Some L2 vowels consistently mapped onto L1 categories well, such as English /i/ and /æ/ which were assimilated onto Spanish /i/ and /a/ at a rate of 93% and with high goodness-of-fit. Conversely, there were vowels that the participants did not categorize strongly onto any Spanish vowel. English /ɔ/ and /ʊ/, for example, were assimilated at a rate of 65% or below for every L1 vowel and had low goodness-of-fit scores. However, as we will see in more detail in the following sections, just because an L2 vowel is consistently assimilated onto the same L1 category with a high goodness of fit rating, it does not necessarily result in accurate discrimination and identification of that sound.

In addition to frequency and goodness scores, another aspect that added to the complexity of perceived L1-L2 vowel similarity was the number of L2 vowels that assimilated onto a single L1 category. Table 2 showed that a single Spanish vowel could be the modal assimilation for multiple English vowels. For example /i/ and /ɪ/ are both consistently assimilated to Spanish /i/ at rates of 93% and 75%, respectively. Similar situations are also found for /e^{ɪ}/-/ɛ/ and /æ/-/ɑ/.

According to Best & Tyler (2007), we expect native Spanish speakers to have the most difficulty perceiving differences between the tokens of these contrasts in the discrimination task because they are heard as equally good instances of the same L1 category.

The manner in which English vowels are categorized onto the Spanish sound system gives us an idea of how similar native Spanish speakers perceive certain L1 and L2 sounds to be. By using PAM-L2's descriptions of assimilation patterns described in Best & Tyler (2007), we predicted the relative ease of discrimination for ten L2 contrasts. The contrasts fell into three patterns; each pattern corresponding to a distinct level of predicted discrimination difficulty:

1. *Single-category* (difficult): /i-ɪ/, /eᴵ-ɛ/, and /æ-ɑ/
2. *Category-Goodness* (relatively easy): /æ-ɔ/, /ɑ-ɔ/, /ɔ-ʊ/, /o-ʊ/, and /ʊ-u/
3. *Double-category* (easy): /ɪ-eᴵ/ and /ɛ-æ/

Discrimination Tasks

As mentioned above, L2 contrasts were placed into one of three assimilation patterns based on how the two sounds of the contrast mapped onto the L1 sound system. It was predicted that all the contrasts belonging to the same assimilation pattern would exhibit the same level of discrimination difficulty for native Spanish speakers. However, the predictions made by PAM-L2 proved to be inadequate. As we saw in section 3, just because the tokens of multiple L2 contrasts are assimilated to the L1 in similar ways it does not necessarily result in the same level of discrimination difficulty. The /i-ɪ/ and /eᴵ-ɛ/ contrasts were both placed into the *single-category* (SC) pattern because the tokens of each were consistently mapped onto the same L1 category. This prediction was uphelp for the /i-ɪ/ contrast because the participants perceived /i/ and /ɪ/ as instances of the same category an average of 58% of the time. However, the /eᴵ-ɛ/

contrasts were accurately discrimination 87% of the time, going against the PAM-L2's prediction.

The reverse is also true: L2 contrasts whose tokens assimilate in different ways to the L1 can still result in the same level of discrimination difficulty for native Spanish speakers. At least one L2 contrast from each of the three assimilation patterns was comprised of tokens that were difficult for native Spanish speakers to discriminate, including: single-category /i-ɪ/, category-goodness /ɑ-ɔ/, and two-category /ɛ-æ/. In fact, the English sounds contained in the /ɛ-æ/ contrast were predicted to be easily discriminated because each token was assimilated onto a different L1 vowel (TC), but as we saw, these two sounds were perceived as *the same* at an average rate of 81%, a higher rate than any other two sounds under investigation.

Integration of Identification Task Discussion

The results from the identification task generally support the level of discrimination difficulty expressed in experiment 2 and not the level of difficulty necessarily predicted by PAM-L2. By analyzing the frequency of correct identifications and cross-misidentifications of the tokens in an L2 contrast, we can see if the two tokens of the contrast are members of the same L2 category. By expanding our view beyond the two-token identification charts and looking at the frequencies of misidentification across the board, we gain a more complete understanding of the participants' perception of these English vowels.

If we look at the four least accurately discriminated contrasts from experiment 2 (/i-ɪ/, /ɔ-ɑ/, /u-ʊ/, /ɛ-æ/) we see similar identification patterns emerge. Tables 7 and 8 show us that in three of these four contrasts, the first token was misidentified as the second more often than it was identified correctly: /i/ was labeled as /ɪ/ 54% of the time, /ɔ/ was labeled as /ɑ/ 54% of the

time, and /u/ was labeled as /ʊ/ 50% of the time. What this suggests is that the native Spanish speaking participants have not yet established L2 categories that distinguish between /i/-/ɪ/, /a/-/ɔ/, and /u/-/ʊ/. Instead, it would be probable that there is one category that encompasses each pair of sounds with one token being a better fit for that interlanguage category than the other. Since /ɪ/, /ɑ/, and /ʊ/ were identified more accurately than the other tokens, it is possible that they are the better fit for this interlanguage category.

What this also shows us is that just because an L2 sound is strongly assimilated to an L1 category, it doesn't mean that it will be identified and discriminated accurately. Even though the English tense vowels /i/ and /u/ were assimilated more frequently to Spanish /i/ and /u/ with better goodness-of-fit ratings than their lax counterparts, /ɪ/ and /ʊ/ in experiment one, it is the English lax vowels that get identified more accurately in experiment three. This supports Cebrian's (2008) claim that we acquire sounds as part of a system, and that the existence of one category (/ɪ/ or /ʊ/) can affect the perception of an L2 category that is perceived to be nearly identical to an L1 category, like English /i/ and /u/.

If we take a look at the two most accurately discriminated contrasts (/$e^{ɪ}$-ɛ/ and /$e^{ɪ}$-ɪ/), we will gain some insight into the importance of having more than one means to measure perception, in terms of category formation. Looking at the two-token identification chart of /$e^{ɪ}$/ and /ɛ/ in Table 9b, we notice two things: first, that these two sounds are not often misidentified as the other (only 6% and 7% of the time, respectively) and second, that the participants correctly identified /$e^{ɪ}$/ (89%) more frequently than /ɛ/ (57%). For this contrast, the low frequency of cross-misidentification and the native Spanish speakers' ability to discriminate the sounds with 87% accuracy (experiment 2), indicates that native Spanish speakers perceive these two sounds to be members of separate L2 categories. However, in order to determine the range of the

sounds contained within these two separate categories, we must analyze the discrimination and identification scores of /eᴵ/ and /ɛ/ against other English vowels.

In table 7 we can see that /eᴵ/ was very rarely identified as any other vowel. This, in combination with the relatively high discrimination rates of the contrasts /eᴵ-ɛ/ and /eᴵ-ɪ/ (84% and 87%), suggests that the category formed by native Spanish speakers that contains /eᴵ/ does not contain much overflow from other English categories.

Such is not the case for /ɛ/. Even though it was also identified as /i/ and /ɪ/ at very low rates, just like /eᴵ/, it was labeled as /æ/ 28% of the time. It appears however that this misidentification is one-sided because /æ/ was labeled /ɛ/ a meager 5% of the time. Additionally, when we employ the results from experiment 2, we see accurate discrimination of /æ-ɛ/ in only 19% of all presentations. Cebrian (2008) claims that such poor L2 category discrimination can be the result of a large overlap in the mental representation of these two sounds, meaning the native Spanish speakers may not have heard the spectral differences between the categories suggesting that both sounds collapsed into one. I would like to posit though that /æ/ is the better exemplar of this category because it was identified much more accurately than /ɛ/ (89%-vs-57%) and because /ɛ/ was labeled as /æ/, but /æ/ was hardly ever labeled as /ɛ/.

Even though using the identification scores accurately determined that /eᴵ/ and /ɛ/ were not part of the same L2 category, it was not until we engaged the results from the identification task and other discrimination pairs that we saw a more accurate view of L2 category formation for /eᴵ/, /ɛ/ and /æ/.

Evaluation of PAM-L2 & Broader Implications

Previous investigations (Flege & McKay, 2004; Rallo Fabra & Romero, 2012) had mixed results when it came to the predictions of PAM-L2, and the current study is not exception. The predictions made by PAM-L2 could not explain the level of discrimination difficulty for four out of ten contrasts. It appears that relying simply on vowel assimilation patterns to predict the difficulty a group of language learners will have when they hear two L2 sounds may not be sufficient.

The identification results never supported the PAM-L2's predictions without first being supported by the discrimination data. Adding a second task to test the discrimination ability of a group of language learners gives more power to PAM-L2's predictions when they are correct, but after further investigation, may also reveal places of weakness.

It was also difficult at times to determine if a contrast had been predicted accurately by PAM-L2 because there was no specific, quantitative guideline that determined an *easy*, *relatively easy*, or *difficult* contrast. Having proportions to use as a guide would aid in the correct interpretation of these discrimination difficulty levels. Even something as general as:

- *Easy discrimination:* 75% correct and up
- *Relatively easy discrimination:* the percentage that is determined to be significantly better than chance up until 74%
- *Hard discrimination:* 0% to just before anything significantly better than chance.

6.0 FUTURE RESEARCH

One point of interest that was impossible to analyze in the present investigation due to methodological reasons was the relationship between /æ/ and /ɑ/. Because /æ/ is a front vowel and /ɑ/ is back, we were unable to use the forced identification task to test their confusability in addition to the discrimination task. These two sounds are of special interest because they were both assimilated onto Spanish /a/ and they were often confused in the discrimination task but both were identified at relatively high frequencies (/æ/-89%; /ɑ/-63%). The question then is, was /æ/ identified accurately because /ɑ/ was not a possible answer, and vice versa? Or were they identified accurately because the native Spanish speakers were aware of the characteristics of these sounds?

In general we saw an uncertainty regarding native Spanish speakers' perception of lower English vowels in the discrimination and identification tasks. This confusion is realized not only in the /ɛ-æ/ discussed at length above, but also by the inaccurate discrimination and poor identification of the first back vowel contrast: /ɑ-ɔ/. However no light could be shed on any vowel contrast that spanned the front-back continuum due to the set up of the identification task. Therefore, although we know native Spanish speakers had a difficult time discriminating between the sounds in the following categories (/æ-ɑ/, /æ-ɔ/, and /ɛ-ɑ/) we do not know if they would be correctly identified or not. A study that investigates the patterns of identification of

these vowels would be beneficial to our overall understand of native Spanish speakers' perception of English vowels.

An investigation regarding the connection between perception and production would be a logical follow up study. In addition to the perception exercises, the native Spanish speakers also participated in two production tasks. A study comparing the vowels of English words produced by native Spanish speakers may help strengthen hypotheses made by PAM-L2 and SLM regarding the links of perception and production.

APPENDIX A

WORDS PRESENTED IN THE PERCEPTION TASKS

Table 12
Words presented in perception tasks

Target Phoneme	Target Words 1 (orthographic)	Target Words 2 (orthographic)
/i/	beat	heat
/ɪ/	bit	hit
/eᴵ/	date	hate
/ɛ/	bet	head
/æ/	bat	hat
/ɑ/	dot	hot
/ɔ/	bought	caught
/o/	boat	coat
/ʊ/	book	hook
/u/	boot	who
These are the words presented to the participants in the vowel assimilation and identification tasks (Due to time constraints, the discrimination task only utilized Target Words 1)		

APPENDIX B

LANGUAGE HISTORY QUESTIONNAIRE[i]

Sex: Male / Female **Age (in years) _____** **Handedness: L / R**

Native country _____ **Years and months spent in the U.S. _____**

Did you attend an English speaking Elementary or High school? Yes / No

This questionnaire is designed to give us a better understanding of your experience learning a second language. Please be as accurate as possible when answering the following questions. Thank you for your participation in this study.

If you need more space to write, please let me know and I will give you more paper.

PART I: Draw a <u>small</u> circle on the map to indicate where you spent most of your childhood.

Arabian Peninsula

Country: _____
City: _____

Latin America

Country: _____
City: _____

1.) Do you have any seeing or hearing problems (corrected or uncorrected)?

_____

2a.) What is your first language (i.e., **language first spoken**)? If more than one, please briefly describe the situations in which each language was used.

_____

_____

2b.) Which language or languages do you consider your second language?

_____

3.) **Living and Traveling Abroad**: Please write the name of the cities and countries where you have spent at least 3 months abroad. Also write the number of months you lived there and the languages you used while you were in the country. (Start with the most recent)

Country visited	# Months there	Language(s) used

4.) List below, from most fluent to least fluent, all of the languages you know. Also specify the age in years at which you began to learn the language and the context you learned it in. For example, "Arabic, birth, home". (**Please remember to list your native language.)**

Language	Age you began (in years)	Learning Situation

5.) What languages were spoken in your home while you were a child?

_____

_____

6.) Please list the language(s) the following people speak.

Mother:
Father:
Closest friend:

7.) How many years have you studied English? Please indicate the setting(s) in which you have had experience with the language (i.e., classroom, with friends, foreign country...)

Number of years:
Setting(s):

Questions 8-11: Please circle one number for each question

8.) Please rate your <u>reading</u> proficiency in English.
(1= not literate, 10= very literate)

1 2 3 4 5 6 7 8 9 10
not literate very literate

9.) Please rate your <u>writing</u> proficiency in English.
(1= not literate, 10= very literate)

1 2 3 4 5 6 7 8 9 10
not literate very literate

10.) Please rate your <u>conversational fluency</u> in English.
(1= not fluent, 10= very fluent)

1 2 3 4 5 6 7 8 9 10
not fluent very fluent

11.) Please rate how well you <u>understand English when other people are speaking</u>.
(1= unable to understand conversation, 10= perfectly able to understand conversation)

1 2 3 4 5 6 7 8 9 10
no comprehension perfect comprehension

12.) What is the hardest part of learning English for you?
Please rank the following from 1 to 4. (1= easiest, 4=hardest)

Pronunciation:_____
Grammar: _____
Vocabulary: _____
Sayings/Expressions:_____

13.) While you in the US:
What percentage of the time do you spend speaking English? _____%
What percentage of the time do you spend speaking your **first** language? _____%

14.) How much time do you spend watching TV, movies, or something similar in **English** per day? (please circle)

less than 1 hour 1-2 hours 3-4 hours more than 4 hours

15.) How much time do you spend watching TV, movies, or something similar in your ***first language*** per day? (please circle)

less than 1 hour 1-2 hours 3-4 hours more than 4 hours

16.) How frequently do you read a newspaper or magazine in **English**?

never once a week three or more times a week

17.) How frequently do you read a newspaper or magazine in your ***first language***?

never once a week three or more times a week

18.) How much time do you spend speaking with native **English** speakers?

hardly ever occasionally often at every opportunity

19.) How much time do you spend speaking with native speakers of your ***first language***?

hardly ever occasionally often at every opportunity

20.) Is there anything else about your language background that you would like to comment on? Please feel free to make comments about things that were not covered on this questionnaire.

[1] This has been adapted from: Tokowicz, N., Michael, E. B., & Kroll, J. F. (2004). The roles of study-abroad experience and working-memory capacity in the types of errors made during translation. Bilingualism: Language and Cognition, 7, 255-272.

APPENDIX C

Table 13
PERCENT MARKED AS 'SAME' IN DISCRIMINATION TASK

		Second Token of Contrast									
		/i/	**/ɪ/**	**/eᴵ/**	**/ɛ/**	**/æ/**	**/ɑ/**	**/ɔ/**	**/o/**	**/ʊ/**	**/u/**
First Token of Contrast	**/i/**	*95%*	74%								
	/ɪ/	41%	*91%*	22%	14%						
	/eᴵ/			*100%*	13%	13%					
	/ɛ/		13%	13%	*96%*	75%	48%	17%			
	/æ/			13%	87%	*91%*	52%	39%			
	/ɑ/				43%	39%	*82%*	61%	17%	17%	13%
	/ɔ/				25%	35%	59%	*86%*	33%	22%	
	/o/						17%	42%	*86%*	25%	22%
	/ʊ/						17%	17%	33%	*95%*	67%
	/u/							17%	32%	50%	*100%*

Table 13: Percent marked as "the same". This table displays the percentage of all the contrasts presented in this investigation. Italicized numbers represent the contrasts that contain two tokens with the same phoneme. (Percentages equal to 2 individual responses or fewer have been omitted)

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