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# The Processing of /ɪ/-/i/ and /ɑ/-/æ/ Contrasts in Spanish-English Bilingualism

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# THE PROCESSING OF THE /ɪ/-/i/ AND /ɑ/-/æ/ CONTRASTS IN SPANISH-ENGLISH BILINGUALISM

A Thesis

by

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ABSTRACT

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The following study utilizes an experimental paradigm known as the Sequence Recall Task (Dupoux et al., 2001) to examine the processing of the English vowel contrasts /ɪ/-/i/ and /ɑ/-/æ/ among Spanish-English bilinguals. Using dominance scores calculated from the Bilingual Language Profile (Birdsong et al., 2011), this study examines the processing of these contrasts relative to a control contrast /u/-/ɛ/ as well as how the processing of these contrasts is modulated by participants' English dominance. A total of 24 Spanish-English bilingual speakers participated in a Sequence Recall Task that targeted the processing of these three contrasts. The results indicate that participants were equally efficient in processing the control contrast of /u/-/ɛ/ and the experimental contrast /ɑ/-/æ/, but not the /ɪ/-/i/ contrast, which appeared to be more difficult than the other two. Furthermore, increased dominance in English was found to correspond with similarly increased accuracy in the processing of the /ɑ/-/æ/ contrast, while the /ɪ/-/i/ contrast remained difficult regardless of English dominance.

# DEDICATION

The completion of this degree and thesis would never have been possible without the lifelong support and encouragement of my family, including my parents, Yvonne and Enrique, and grandparents, Margarita and Juan. From a young age you all instilled in me the importance of an education and a love of learning that I have carried with me my entire life. This work is the culmination of almost 23 years of unconditional love, support, and sacrifices that you have made for my sake.

Furthermore, none of this would have been possible without the support and guidance of the educators I have encountered throughout my life, both before and during my time at UTRGV. In particular, I have the wonderful members of my committee (Drs. Ortín, Foreman, and Eom) to thank for the completion of this thesis and degree. I am fortunate to have had the opportunity to be your student and learn from such talented and knowledgeable minds.

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I'd further like to acknowledge my partner, Jon, and his brother, Christian, for lending me the laptop that made it possible to conduct this entire experiment. I am not kidding when I say that this would have been impossible without your contribution.

Further thanks goes out to everyone who has bared with me and kept me sane throughout this endeavor, including my friends, family, and partner. Even as my career as a student comes to an end, the memories of the laughter and company that we have shared over the past five years never will.

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# CHAPTER I

## INTRODUCTION

Common among contemporary theories on the learning of sounds is the notion that the acquisition of sounds in a learner's second language (L2) is influenced by the phonology of the learner's first language (L1). One of these theories, Best's (1995) Perceptual Assimilation Model (PAM), holds that the learning of sounds in a second language is influenced by how similar or dissimilar the sounds are to sounds in the learner's first language, with sounds that are more dissimilar being easier to learn. Under this model, L2 sounds that a learner perceives as being similar to sounds in their L1 run the risk of being assigned to pre-existing L1 phonological categories. That is to say, if a learner interprets two L2 sounds as being similar to or the same as an L1 sound, both L2 sound runs the risk of essentially being "remapped" to the similar L1 sound and perceived as such, in a process known as assimilation. As a result of this, the learner may then be unable to discriminate between the new L2 sounds, and thus have difficulty fully acquiring the phonology of their L2. Among speakers of Spanish, one English contrast that has been found to pose a difficulty for them is that of /ɪ/-/i/, which marks the difference between English words such as *bit* and *beat*, respectively. This difficulty arises due to English possessing a larger vowel inventory than that of Spanish. As a result of this increased vowel inventory, Spanish-speaking learners of English must learn additional vowels that do not have perfect corollaries in Spanish, and which are not meaningfully different from the vowels they do possess. That is, in the case of the /ɪ/-/i/ contrast, Spanish possesses only the vowel /i/,

whereas English possesses both /ɪ/ and /i/. Because Spanish does not possess /ɪ/ like English, speakers of Spanish are not accustomed to distinguishing between the two English sounds. Furthermore, because Spanish makes use of less vowels when compared to English, Spanish speakers must assimilate these English vowels to a limited selection of vowels, which further limits their ability to accurately perceive contrasts between them.

Theories like the PAM are not just applicable to late L2 learners however. In the case of Spanish and English bilinguals again, the /ɑ/-/æ/ contrast present in English words such as *pot* and *pat*, has also been shown to be difficult to discriminate for early and late Spanish-English bilinguals. In this case, both/ɑ/ and /æ/ are absent from the phonology of Spanish, but they are similar to Spanish vowel /a/. While this may initially come as a surprise given that bilinguals are exposed to the phonologies of both languages unlike late L2 learners, studies on bilingual speakers have demonstrated that they are capable of exhibiting variance in their language abilities that deviate from monolingual norms. That is, behaviors that may be uncommon among monolinguals are often to be expected when it comes to bilinguals. These differences exist not just between bilinguals and monolinguals, however, but also among bilingual speakers of the same two languages. One factor that has been found to account for these differences between bilinguals is that of dominance. In other words, speakers of the same two languages (in our case, English and Spanish) may still exhibit differences in their language abilities depending on how dominant they are in either of their languages. These effects of dominance on bilinguals' language abilities extends not just to production (Amengual, 2016; Kim & Repiso-Puigdelliura, 2019)—their ability to produce sounds—but also to perception, their ability to understand and process different sounds (Amengual & Chamorro, 2015; Bosch & Ramon-Casas, 2011; de la Fuente Iglesias & Perez Castillejo, 2019; Piccinini & Arvaniti, 2018; Ortín, 2022). In the present

study, we seek to unveil how Spanish-English bilinguals process the /ɪ/-/i/ and /ɑ/-/æ/ English contrasts. More concretely, we want to know the extent to which they are able to process them and whether their processing is modulated by bilinguals' dominance.

# CHAPTER II

# REVIEW OF LITERATURE

## Theories on the Learning of Sounds

Multiple theories have been proposed to explain the learning of L2 phonology and sounds, and common among these is the stance that the learning of speech sounds in a foreign language is influenced by the learner's native language (Shea, 2019). The Contrastive Analysis Hypothesis (CAH) attributes difficulties in second language acquisition (which includes, but is not limited to, the learning of L2 sounds and phonology) to interference from the learner's first language, in what is known as negative transfer. That is to say, differences between the linguistic systems of the learner's L1 and L2 may cause conflicts that result in the learner experiencing difficulty acquiring certain aspects of the L2. By identifying these differences between two languages, the CAH also posits that predictions can also be made as to how difficult different aspects of the L2 in question will be for learners to acquire, in what is known as a hierarchy of difficulty. While this hierarchy can be used for any two languages, Prator (1967) originally used it with differences between English and Spanish as examples, and outlined six different levels in this hierarchy of difficulty. They are, in ascending order of difficulty: transfer (Level 0), coalescence (Level 1), underdifferentiation (Level 2), reinterpretation (Level 3), overdifferentiation (Level 4), and split (Level 5). In instances of transfer (or more specifically, positive transfer) no conflicts exist between the first and second language such that the learner

can easily transfer over an aspect of their first language to the second. In the case of coalescence, what exists as two separate items in the learner's L1 are instead only one item in the L2, so the learner must learn to overlook the distinction in their L1. In the case of underdifferentiation, an item that is present in the L1 is absent in the L2. In instances of reinterpretation, a pre-existing L1 item takes new forms or distributions. Overdifferentiation, the opposite of underdifferentiation, occurs when a new item is introduced in the L2 which bears no similarity to those in the L1. Split occurs when what is a single item in the L1 becomes two or more in the L2. This last case is the one that applies to the contrasts under investigation. Both the /ɑ/-/æ/ and the /ɪ/-/i/ contrasts appear to be assimilated into one Spanish phone. According to this theory, the learning of each of these two contrasts is predicted to be very difficult for Spanish learners.

The Speech Learning Model (SLM) developed by Flege (1995) proposes an equivalence classification by which new sounds are associated to existing phonological categories developed from experience with the listeners' first language. According to the SLM, the formation of new L2 categories is dependent on whether the L2 sounds are too similar or too different from existing L1 categories. Acquiring sounds in the L2 that are more distinct from those present in the L1 will likely cause the creation of a new L2 category, while L2 sounds that are perceived as similar to L1 categories will be stored as the existing L1 category and will not yield the development of a new L2 category. This second scenario may hinder the learning of the phonetic aspects of the L2 sound as speakers may comfortably rely on the phonetic aspects of their L1 category. However, this model is not helpful for the contrasts under investigation because it focuses only on the formation of new L2 phonological categories, rather than the perceptual difficulty that arises from the failure to successfully form these new L2 categories.

Best's (1995) Perceptual Assimilation Model (PAM) also concerns itself with how non-native speech sounds are perceived by a listener, although it focuses on the difficulty of L2 contrasts rather than L2 categories. Similar to the SLM, this model posits that non-native speech sounds are perceived in relation to how similar or dissimilar they are to sounds and contrasts in the listener's native language. Sounds that are perceived as similar to other sounds in the L1 pose the most difficulty for listeners to discriminate due to the perceived similarity between the native and non-native sounds. The PAM focuses on how new sounds are perceived and remapped onto phonological categories existing in the L1. It predicts three different scenarios for this remapping, or assimilation, of L2 sounds into L1 phonological categories, and makes predictions as to how effective listeners might be in discriminating a new contrast. The first scenario is the two-category assimilation, in which both members of a contrast are assimilated to two distinct L1 categories. Discrimination of this type of contrast is expected to be excellent as the listener is dealing with two established phonological categories. The second scenario is the single-category assimilation, in which two L2 phonemes are mapped onto one single L1 category. Discrimination in this case is expected to be poor. But it may be the case that one of the pairs in the L2 contrast is a better exemplar of the L1 category than the other, leading to a third scenario called category goodness assimilation. Discrimination of the new sounds in this case is expected to be between those in the previous two scenarios.

This model is especially useful for the contrasts under investigation as it offers an explanation for speakers' difficulty in discriminating these contrasts that are not present in Spanish. That is to say, under the PAM, the perceptual difficulty involving these contrasts may very well be a case of goodness or single-category assimilation.

It must be noted that phonological and phonetic differences between two languages cannot only create instances of crosslinguistic influence in late second language learning. Extant studies on human cognition and phonology have found that, for individuals that know more than one language, each of these languages can influence the other (Shea, 2019). These effects are found regardless of order of acquisition, age of acquisition or L1-L2 status. For example, when it comes to the influence of the L2 into the L1, Osborne and Simonet (2021) found that experience with English as a foreign language affected native Portuguese speakers' productions of voiced stops in Portuguese. With regards to early bilingualism, Lee-Ellis (2012) found that Korean-English bilinguals' processing of the Korean tense-lax /s/-/s*/ contrast was influenced by their experience with English (as this contrast is absent in English phonology), and Ortín (2022) found that Spanish-English bilinguals' processing of lexical stress was influenced by linguistic dominance and knowledge of Spanish (lexical stress processing is relevant in Spanish and less so in English). Thus, the case made here about the English contrasts under investigation (namely /ɪ/-/i/ and /ɑ/-/æ/) and how they relate to native Spanish speakers is relevant not only in cases where English is learned as a second language, but also in Spanish-English early bilingualism.

## The /ɑ/-/æ/ and /ɪ/-/i/ Contrasts

When it comes to vowel inventories, English has been found to possess a much larger vowel inventory when compared to Spanish. Escudero and Chládková (2010) identify nine full monophthong vowels in American English: /i/, /ɪ/, /ɛ /, /æ/, /ɑ/, /ʌ/, /ɔ/, /ʊ/, and /u/, though there also exists /ə/, which brings the number of monophthongs up to ten. Spanish on the other hand possesses a vowel inventory of a mere five vowels: /i/, /e/, /a/, /o/, and /u/ (Bradlow, 1995; Clopper et al., 2005). This smaller vowel inventory of Spanish when compared to English necessitates the assimilation of these English vowels into a much smaller selection, which can

cause multiple instances of single-category assimilation. For example, Casillas and Simonet (2015) tested early and late Spanish-English bilinguals in Arizona in a discrimination experiment testing the /ɑ/-/æ/ contrast, which Spanish speakers appear to assimilate to their L1 vowel /a/. They found that even early bilinguals who were exposed to English from an early age differed from English monolinguals in their discrimination of this contrast, suggesting that phoneme boundaries were not robust, and thus, early and late learners' discrimination was influenced by their experience with Spanish. Recall also that the second scenario described by the PAM, where two members of an L2 contrast are assimilated into a single L1 phonological category (that is, single-category assimilation), predicts that learners will thus exhibit difficulty discriminating between the two members of the contrast. Given that these vowels, /ɑ/ and /æ/, which are being assimilated to the same Spanish vowel at least some of the time, it follows then that contrasts between the two would be difficult for Spanish-speaking listeners to process.

Similarly, a single-category assimilation case has also been reported for the /ɪ/-/i/ contrast for Spanish speakers, which further explains why this contrast poses problems for speakers of this language. Escudero and Boersma (2004) found that Spanish speakers assimilated the English vowel /i/ to the Spanish vowel /i/, and the English vowel /ɪ/ to both Spanish vowels /i/ and /e/. This provides evidence that boundaries of this contrast may well not be robust. It is also important to note that Spanish speakers have been found to vary in their reliance of different acoustic cues to perceive this contrast regardless of experience with English (Casillas, 2015; Kondaurova & Francis, 2008). Finally, studies looking at the training of members of this contrast (among other vowels) have found that the identification of vowel /i/ tends to be challenging even after explicit training (Fouz-González & Mompean, 2021).

## The Sequence Recall Task

This study utilizes a task known as the sequence recall to examine how bilinguals process the /ɑ/-/æ/ and /ɪ/-/i/ contrasts. The sequence recall task is a memory-taxing task first used by Dupoux et al. (2001) to study stress deafness. It is much more demanding than other experimental paradigms used in other studies on speech perception and processing (Ortín & Simonet, 2023). This task puts participants' processing abilities to the limit and requires the correct reporting of a series of minimal pair items. Importantly, the nature of the contrast involved in the minimal pair can affect participants' accurate recalling and reporting of the items if the contrast does not hold a privileged status in the participants' phonological system.

Dupoux et al. (2001) originally developed this paradigm to assess participants' processing of stress contrasts. Their study tested French and Spanish monolingual listeners and found that phonetic variability in the stimuli as well as the memory load imposed in the task was able to yield a nonoverlapping distribution of results with regards to the two languages. French speakers' accuracy was lower than that of Spanish speakers, arguably because stress is a feature that is relevant for Spanish phonology but not for French phonology. Therefore, experience with French (which implies lack of experience with lexical stress) caused French monolingual speakers to not develop strong stress-based phonological categories, which, in turn made their participation in the task difficult when dealing with stress contrasts.

Previous evidence in the field of bilingual phonology has attested the role of memory load on unveiling varying processing abilities in bilinguals as a by-product of crosslinguistic influence (Lee-Ellis, 2012; Ortín, 2022). This means that beyond their perceptual capabilities, bilinguals may display variance in the processing of phonological units. The present experiment is concerned with deep phonological processing routines of these contrasts in the presence of

high memory load conditions, which has not been tested to date in any vocalic contrast or in any population.

It is important to note that in order to assess the processing of the experimental contrasts, this task typically includes a control contrast, one that is not predicted to pose any problems for any of the participants. This provides a processing baseline and tells us to what extent each individual's behavior is influenced by the memory load present in the task in a condition that is "easy". In the original experiment by Dupoux and colleagues, the target contrast was stress, and the control contrast was a series of consonantal contrasts that were relevant for the phonologies of participants. This allowed for the comparison of the contrast being tested relative to a control contrast. In the case of our study, we added an additional English vowel contrast: /u/-/ɛ/. This contrast should not be difficult for Spanish-English bilinguals since both members are assimilated to different Spanish contrasts: /u/ and /e/ respectively (Escudero and Chládková, 2010).

## Linguistic Dominance on the Learning of Sounds

Age has been found to be a critical factor in language development and the learning of sounds. Particularly, studies on bilinguals have demonstrated that the age of acquisition is a major predictor of native-like production and perception of the L2 (Flege, 2003; Flege et al., 1999; Oyama, 1976), due likely to the fact that the first year of life is the period where infants are still able to discriminate sounds that may not exist in the phonology of their L1 (Bosch & Sebastián-Gallés, 2003; Kuhl et al., 2006; Polka & Werker, 1994; Sebastián-Gallés, 2006). Accordingly, early acquisition of multiple languages at the same time (what is known as simultaneous acquisition) would appear to result in the speaker's ability to successfully perceive and produce the sounds of both languages (Sundara et al., 2006; Sundara & Polka, 2008).

Simultaneous acquisition in particular appears to be the crucial factor in ensuring these abilities, as studies on learners who acquired their languages sequentially (that is, one after the other), rather than simultaneously, show that they still exhibit some perceptual difficulty, even if the two languages were acquired early in life (Pallier et al., 1997; Sebastián-Gallés & Soto-Faraco, 1999).

Early age of acquisition among bilingual speakers has also been found to result in a tendency for bilingual speakers to display phonological/phonetic systems more akin to that of monolingual norms of their languages, as speakers are exposed early in childhood to the phonology of their first language, and in later childhood to that of their L2, and are thus able to better develop the phonologies of both their languages (Chang, 2016; Lukyachenko & Gor, 2011). On the other hand, departure from monolingual norms among bilingual speakers is generally attributed to proficiency and experience (Au et al., 2008; Chang & Yao, 2016; Rao, 2015; Ronquest, 2012). Ronquest (2012) found that heritage speakers who frequently traveled to Spanish-speaking countries and made use of Spanish outside of the classroom possessed vowel space more similar to that of monolingual native Spanish speakers. Konopka and Pierrehumbert (2008) also found differences in the vowel spaces of bilingual Spanish speakers, finding that Mexican heritage speakers and Spanish L1/English L2 speakers near Chicago displayed greater assimilation of tense and lax vowels, while early bilinguals displayed less assimilation.

We must take into account that bilinguals are not two monolinguals in one. The language systems of bilinguals do not exist independently of each other, and even speakers of the same two languages are capable of demonstrating variability in various aspects of their languages, such as production and perception (Shea, 2019). Dominance is one such influence that has been found to explain these differences in bilinguals' production and perception. Dominance has been

described as a “bilingual’s relative abilities in each of their two languages” (Olson, 2023). Thus, dominance is a relative measure which is obtained by comparing bilinguals’ abilities and experiences in their two languages. It has been conceptualized in many different ways (see Olson, 2023 for a review), but, overall, it appears that dominance is a construct that encompasses the linguistic experiences, practices and abilities of bilinguals.

Amengual (2016) found that Spanish-dominant bilinguals produce taps more accurately than English-dominant bilinguals. Furthermore, studies on balanced bilinguals have demonstrated that they are able to distinguish L1 and L2 phonemic contrasts, whereas bilinguals who are more dominant in one language exhibit transfer from their dominant language to their less dominant one (Amengual & Chamorro, 2015; Bosch & Ramon-Casas, 2011; de la Fuente Iglesias & Perez Castillejo, 2019; Piccinini & Arvaniti, 2018). Similar findings have been reported by Kim and Repiso-Puigdelliura (2019), who found that the production of taps by Spanish-English bilingual speakers is also affected by their language dominance. In terms of processing, previous research also demonstrates that dominance and experience are capable of influencing the processing of phonological features, such as stress. For example, Spanish-English bilinguals processing of stress contrasts has been found to be modulated (at least in part) by dominance and knowledge of Spanish (Ortín, 2022).

It is clear, then, that dominance is an important factor in phonetic and phonological performance in bilingualism. In this study, we assess whether dominance plays a role in bilinguals’ processing of the vocalic contrasts /ɪ/-/i/ and /ɑ/-/æ/.

## Research Questions

The research questions we pose for the present study are the following:

RQ1: How do bilinguals process the /ɪ/-/i/ and /ɑ/-/æ/ contrasts as compared to the control contrast /u/-/ɛ/?

RQ2: Does dominance modulate participants' performance in contrasts /ɪ/-/i/ and /ɑ/-/æ/?

With regards to RQ1, drawing from previous studies on bilingual perception (Casillas & Simonet, 2015) and the learning of English vowels as a second language (Fouz-González & Mompean, 2021; Kondaurova & Francis, 2008), we hypothesize that these contrasts remain difficult for Spanish-English bilinguals, especially at a processing stage with increased memory load demands.

When it comes to RQ2, previous studies have attested the role of linguistic dominance in the phonological behavior of bilinguals (Amengual & Chamorro, 2015; Bosch & Ramon-Casas, 2011; de la Fuente Iglesias & Perez Castillejo, 2019; Piccinini & Arvaniti, 2018; Shea, 2019). We hypothesize that stronger dominance in English will fare higher processing abilities in bilinguals for each of the contrasts.

# CHAPTER III

# METHODOLOGY AND FINDINGS

## Methodology

The following chapter discusses methodology and findings of the experiment, including participants, experiment, procedure, and data analysis.

### Participants

Participants were 24 Spanish-English bilingual undergraduate students at a public university in the south of the United States, which was located in the Spanish-English bilingual community of the Rio Grande Valley in South Texas. This region is located along the US-Mexico border and is home to a predominantly Spanish-speaking population (Christoffersen, 2019). In fact, about 78.2% of individuals in this community have been reported to speak a language other than English at home (USCB, 2010).

Participants in this study were bilingual speakers of Spanish and English. According to their self-reported linguistic background gathered using the Bilingual Language Profile (Birdsong et al., 2012), the group was heterogeneous in terms of age of acquisition of English and dominance. Six of the participants were male and eighteen were female. Their ages were between 18 and 27 ($M$=22.04, $SD$=2.01). All of the participants were native speakers of Spanish, which means that they were exposed to Spanish since birth. However, they differed in the age at which they were first exposed to English. This means that the bilingual group is composed of

Spanish speakers who were exposed to English at different ages, which yielded a group that includes individuals whose experience can be found in between early Spanish-English bilinguals (or early bilinguals) and Spanish native late L2 learners of English (the latest age of exposure to English reported by a participant was 13).

It is important to note that our bilingual participant group is not divided into any smaller groups for the purpose of this study. It is obvious that our bilingual participants are not comparable in terms of onset of acquisition or dominance (see BLP results below), but we take bilingualism as a continuum rather than a construct that can be further subdivided into smaller groups. Our interest lies in the effects that individual linguistic dominance could exert in their processing of the target vowel contrasts. Therefore, we treat all the bilingual participants who participated in this study as one group and further examine how their individual traits in terms of dominance correspond to changes in the processing of vowel contrasts.

**Instrument**

Participants' linguistic dominance was assessed using the Bilingual Language Profile (BLP) questionnaire developed by Birdsong et al. (2012). This tool uses information provided by participants in four equally weighted modules: language history, language use, language proficiency, and language attitudes. The responses to each of the questions across these four modules are numeric. The resulting analyses of the responses yields four scores, one for each module, with a maximum numeric value of 54.5 each. The sum of the scores for every module results in an index of language dominance. Each individual final score can vary from +218 to -218. Scores at the endpoints of the spectrum indicate clear dominance in one language. In the case of this study, negative values were associated with dominance in Spanish while positive

values were associated with dominance in English. A score of or around 0 indicated “balanced” bilingualism.

The data from the BLP for our bilingual group are reported in Table 1 and their distributions are reported in a density table in Figure 1. In the case of our participants, it appears that the mean dominance score is somewhat trending towards dominance in English as it is not close to 0, but also not too high (56.8). This trend can be further observed in the minimum and maximum values. The minimum value indicates that the participant that is the most dominant in Spanish is displaying a modest dominance towards Spanish (-63.65), while the participant that is the most dominant in English has a high score (155.74). Therefore, our group of participants appears to not represent the whole spectrum of dominance in Spanish and English bilingualism as measured by the BLP. As a group they tend to lean more towards dominance in English than in Spanish.

Table 1

*Dominance Score Values (Mean, Standard Deviation, Minimum, Maximum) for the Bilingual Group*

| Mean dominance score (standard deviation) | Minimum | Maximum |
|---|---|---|
| 56.8 (56.1) | -63.65 | 155.74 |

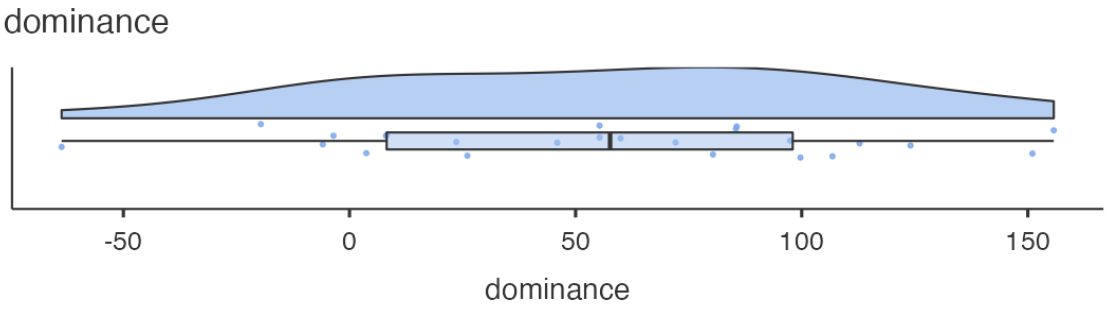


Figure 1

*Density Plot of The Dominance Scores for the Bilingual Group*

**Experiment**

A native speaker of English who grew up monolingual was recorded producing the following nonwords /'tibən/, /'tɪbən/, /'pægəl/, /'pɑgəl/, /'tugəl/ and /'tɛgəl/. Each nonword was recorded 10 times. These productions were used to design the trials for each of the contrasts used in this study. /'tibən/ and /'tɪbən/ were used to test the contrast /ɪ/-/i/; /'pægəl/ and /'pɑgəl/ were used to test the contrast /ɑ/-/æ/; and /'tugəl/ and /'tɛgəl/ were used to test the control contrast /u/-/ɛ/. The first two contrasts are our experimental items that allow us to assess participants' behavior in the /ɪ/-/i/ and /ɑ/-/æ/ contrast. Meanwhile, the third minimal pair represents an "easy" contrast /u/-/ɛ/, which is used as a baseline. We made use of this contrast because each of the phonemes correspond to two different Spanish vowels, namely /u/ and /e/. Thus, discriminating this contrast and processing it expected to be easy for Spanish-English bilinguals. For each contrast a total of 24 trials were designed, 8 for each sequence lengths included in the study (2, 4, 6). The same sequences were used for all the contrasts in the present experiment, and they can be found in Appendix B. Sequences were randomized for each participant in every block. Different productions of the same non-words were used to design the trials, so even when the word /'tibən/

was present four times in a sequence of six, each of those instances of the nonword were different at a phonetic level. Therefore, participants could not rely on their acoustic memory to categorize the items in the trials. They had to resort to their phonological structure.

**Procedure**

The experiment was approved by the Institutional Review Board for Human Subjects Research at UTRGV and was conducted with participants individually in a private office at UTRGV. Prior to beginning the experiments, participants were asked to fill out the Bilingual Language Profile (Birdsong et al., 2012). They were given a participant number, written on a small sticky note for their reference, which they were instructed to enter when asked at the beginning of every task.

Once this was completed, they were introduced to the experiment, beginning with the control condition. It was explained to them that their task would consist of pressing keys on the keyboard corresponding to sounds that they heard, and first they were told to press the keys to hear the corresponding nonwords. For example, the nonword /'tugəl/ was associated to key 1 and the nonword /'tɛgəl/ was associated to key 2. They were instructed to practice associating each key with their respective sound, and then to begin a practice portion of the experiment once ready. This practice session asked participants to indicate the word they heard by using the keys 1 or 2. Visual feedback was provided to participants in this practice and all participants had to accurately complete a trial of 10 items in order to move on to the real experiment. If they made any mistakes, the practice session would repeat until they correctly responded to all 10 items. Once participants had completed the practice portion of the experiment, they were instructed that they would hear the auditory nonwords in sequences of two items followed by the word “OK”, and their task was to indicate the sequence they heard using the keys 1 and 2. For example, if

they heard /'tugəl/-/'tɛgəl/ they had to input 12 and if they heard /'tugəl/-/'tugəl/ they had to input 11. Once this was explained and they understood the task they were allowed to start with the experiment. They were tested first on sequences of 2, then on sequences of 4 and finally on sequences of 6. Each sequence contained eight trials following the order used in the original experiment (Dupoux et al., 2001). Participants completed the same procedure in three blocks, first for the control contrast /'tugəl/-/'tɛgəl/ and then the order of the other two blocks (one for the experimental contrast /'tibən/-/'tɪbən/ and another for the experimental contrast 1-/'pɑgəl/) were counterbalanced. That is, each participant would begin with the non-experimental stimuli. Then, the first participant would be presented with the /ɪ/-/i/ stimuli, followed by the /ɑ/-/æ/ stimuli. The second participant would be presented with the non-experimental stimuli followed by the experimental stimuli in reverse order, then the pattern would repeat for subsequent participants. Once participants completed all three blocks of the experiment they were thanked for their participation and allowed to leave, and the next participant was allowed in. Due to the training portion requiring participants to correctly respond to all 10 tokens before beginning the actual experiment, the time it took for each participant to complete the experiment varied. Most were able to complete it within approximately 20 minutes, not including the time it took for each participant to complete the BLP. For those who had to repeat the training portion multiple times, however, it could have extended past 30 minutes.

Participants were only able to participate one at a time due to resource limitations. The experiment had to be run on a laptop which was transported to and from the office where the experiment took place. A laptop was provided by the university to be used for the experiment, but it was discovered that the experiment was extremely demanding on the laptop's resources to the point that the experiment would freeze during the sequences of 4 or 6. This could only be

solved by forcibly closing the experiment through the laptop's task manager, which then required the restarting of the entire experiment. This problem was eventually resolved by the borrowing of a laptop meant for video games, which possessed more RAM than the university-provided one and was thus able to handle the experiment. However, because the laptop was borrowed this also limited its availability. The massive size and weight of the laptop further made it difficult to transport, and the time it took for participants to complete the experiment, as well as the need to coordinate meeting with each participant, further made the experiment demanding to carry out. This contributed largely to the sample of only 24 participants. While an online version of the experiment was possible, this required payment for each participant, which was outside of the realm of possibility.

**Data Analysis**

The data consisted of by-participant accuracy scores for each contrast (/ɛ/-/u/, /ɑ/-/æ/, /ɪ/-/i/) across the two different sequence lengths (4, 6). Data from the sequence of two were not included. First, because these were treated more as a training sequence and, second, because these trials were considered as easy and did not tap on the phonological processing stage under investigation.

The data were explored in two different ways. First, we addressed RQ1 and analyzed the behavior of the bilingual group to observe the overall patterns in terms of efficient phonological processing of the contrasts included in the study. In order to do that, we submitted the data to a repeated measures ANOVA to assess the contributions of the contrast (/ɛ/-/u/, /ɑ/-/æ/, /ɪ/-/i/) and length conditions (2, 4, 6) to the accuracy metric. Post-hoc pairwise comparisons followed to further understand the results from the omnibus repeated measures ANOVA.

Next, we addressed RQ2 and investigated whether participants' dominance modulates the processing of the experimental contrasts. In order to do that, we carried out two Pearson's correlations between the accuracy data from each of the experimental contrasts (/ɑ/-/æ/, /ɪ/-/i/) and participants' dominance scores.

# CHAPTER IV

# RESULTS

Table 2 summarizes the group's accuracy scores as a function of contrast and sequence length. Figure 2 represents a boxplot of the results.

Table 2

*Proportion Correct Scores (on a Scale From 0 to 1) From the Bilingual Participants as a Function of Contrast (/ɛ/-/u/, /ɑ/-/æ/, /ɪ/-/i/) and Sequence Length (2, 4, 6)*

| Contrast | *Sequence of 2* | *Sequence of 4* | *Sequence of 6* | *Total* |
|---|---|---|---|---|
| /ɛ/-/u/ (control) | .938 (.122) | .849 (.202) | .406 (.203) | .731 (.293) |
| /ɑ/-/æ/ | .964 (.068) | .797 (.172) | .354 (.214) | .705 (.301) |
| /ɪ/-/i/ | .885 (.205) | .708 (.204) | .281 (.170) | .625 (.319) |

*Note. The sequence length of 2 is included here for informative purposes but remember that it is not included in the analyses.*

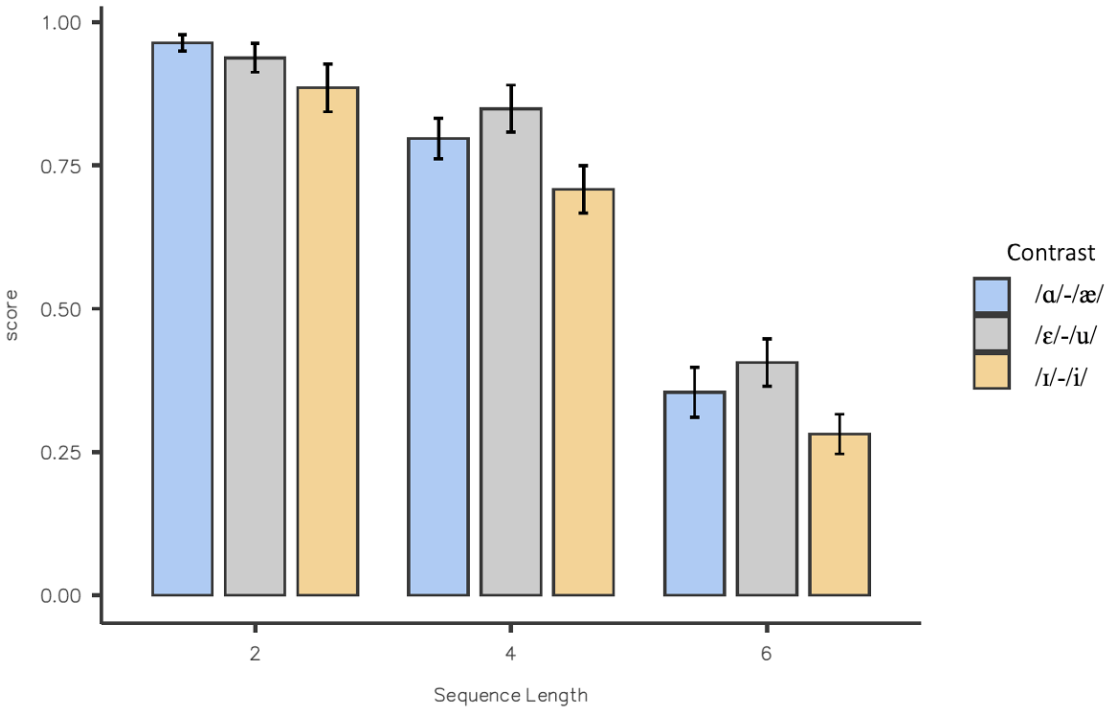


Figure 2

*Proportion Correct Scores (on a Scale From 0 to 1) as a Function of Sequence Length (2, 4, 6) and Contrast (/ɛ/-/u/, /a/-/æ/, /ɪ/-/i/).*

**RQ 1**

The first analysis explores the processing patterns of our bilingual group. With this analysis we seek to unveil whether the experimental contrasts (ɑ/-/æ/, /ɪ/-/i/) are more difficult to process than the control contrast (/ɛ/-/u/). Should participants find the experimental contrasts more difficult to process than the control, we should be able to capture it in their reporting accuracy. The accuracy rates were submitted to a repeated measures ANOVA with Contrast (/ɛ/-/u/, /ɑ/-/æ/, /ɪ/-/i/) and Sequence Length (4, 6) as factors. The ANOVA yielded statistically significant effects for Contrast, $F$ (2, 23) = 5.851, $p < .01$, $\eta^2_p = 0.203$, and Sequence length, $F$ (1, 23) = 269.28, $p < .001$, $\eta^2_p = 0.921$, but no statistically significant interaction between both, $F$ (2, 23) = 0.044, $p > .5$, $\eta^2_p = 0.002$. Post-hoc t-tests were used to make pairwise comparisons (reported in Table 3) and they revealed an asymmetry in the two experimental conditions: while

participants' accuracy in the contrast /ɑ/-/æ/ was not statistically different from the control contrast /ɛ/-/u/, the experimental condition /ɪ/-/i/ appeared to yield more errors than both the control and the /ɑ/-/æ/ contrast.

To summarize, it appears that the processing of contrasts /ɑ/-/æ/ and /ɛ/-/u/ is equally efficient in this bilingual population. Meanwhile, the processing of the /ɪ/-/i/ appears to be more challenging than the other two contrasts as revealed by accuracy data.

Table 3

*Post-Hoc Pairwise Comparisons with Proportion Correct Scores as Dependent Variable and Contrasts as Factor*

| Condition 1 | Condition 2 | df | *t* | $p_{tuckey}$ | $M_{diff}$ | $SE_{diff}$ |
|---|---|---|---|---|---|---|
| /ɛ/-/u/ | /ɑ/-/æ/ | 23 | 1.24 | > .4 | 0.05 | 0.04 |
| /ɛ/-/u/ | /ɪ/-/i/ | 23 | 3.02 | < .02 | 0.13 | 0.04 |
| /ɑ/-/æ/ | /ɪ/-/i/ | 23 | 2.67 | < .04 | 0.08 | 0.03 |

**RQ 2**

The second analysis seeks to explore whether participants' dominance is able to predict or modulate participants' performance in any of the two experimental contrasts. In order to test that, we calculated a contrast effect measure for each of the two contrasts under investigation, /ɑ/-/æ/ and /ɪ/-/i/. This contrast effect metric was equal to the difference between the control condition and each of the experimental conditions. The reason behind this is the following: the control condition gives us a baseline of each participant's behavior in an "easy" contrast in each of the two sequence length conditions. Thus, the contrast effect is a normalized score that measures how much more difficult it is to process each of the experimental conditions relative to the "easy" control contrast. Then, these two metrics (contrast effect metric for /ɑ/-/æ/ and

contrast effect metric for /ɪ/-/i/) were correlated against BLP dominance scores. Pearson's correlations revealed an association only between dominance and the contrast effect metric for /ɑ/-/æ/, $r$=-0.449 [-.05, -.72], $p < .03$, but not for the contrast effect metric for /ɪ/-/i/, $r$=-0.278 [.14, -.61], $p > .1$.

To summarize, we found modest evidence of an association between dominance and the processing of the /ɑ/-/æ/ contrast. The more participants' dominance leans towards English, the better they are at processing this contrast. Meanwhile, we found no evidence of correlation between dominance and the processing of the contrast /ɪ/-/i/. This means that improvement in the processing of this contrast is not associated with changes in the dominance of participants and/or their experience with English.

# CHAPTER V

## DISCUSSION AND CONCLUSION

Our first research question asked how English-Spanish bilinguals processed the experimental contrasts of /ɪ/-/i/ and /ɑ/-/æ/ as compared to the control contrast of /ɛ/-/u/. All the contrasts were tested using the Sequence Recall paradigm which imposes a great amount of memory load on participants. We hypothesized that these contrasts would remain difficult for Spanish-English bilinguals, especially at a processing stage with increased memory load demands. Results indicate that the /ɪ/-/i/ contrast is more difficult to process than the other two. Meanwhile, there were no statistical differences between the processing of the control contrast and /ɑ/-/æ/. Therefore, it appears that the /ɑ/-/æ/ contrast is not as difficult as predicted and that experience with English allows bilinguals to process it similarly to the "easy" /ɛ/-/u/ contrast.

Results also indicate that sequence length was also a significant factor in the accuracy of responses by our participants. This is not surprising since recalling sequences of six items pose more processing challenges than recalling sequences of four items. A higher number of items makes pushes participants' memory more and chances of unsuccessful reporting increase. This effect is not unexpected, and it has been previously found in studies using the Sequence Recall Task (Dupoux et al., 2001; Ortín, 2022; Ortín & Simonet, 2022).

Our second research question asked if language dominance modulated participants' processing of the contrasts /ɪ/-/i/ and /ɑ/-/æ/. We hypothesized that stronger dominance in

English would be associated with higher processing abilities in bilinguals for each of the contrasts. We subtracted participants' scores on each of the experimental contrasts from their scores on the control contrast and correlated this score with participants' dominance scores. We found modest evidence that participants' English dominance accounted for the processing of the /ɑ/-/æ/ contrast but not for the /ɪ/-/i/ contrast. The results indicate that dominance plays a role only with regards to the /ɑ/-/æ/ contrast, but the /ɪ/-/i/ contrast remains difficult regardless of dominance. The results for the /ɑ/-/æ/ contrast are not unexpected, given the difficulty of the contrast has been reported in findings by those such as Casillas and Simonet (2015), who found Spanish-English bilinguals assimilated /ɑ/-/æ/ to Spanish /a/. The results for the /ɪ/-/i/ contrast are also not too unsurprising on their own, as findings by Fouz-González & Mompean (2021) have demonstrated that identification of /i/ is particularly difficult. Furthermore, these results are also in line with those by Escudero and Boersma (2004), who reported assimilation of /ɪ/ and /i/ among Spanish speakers to Spanish /i/, at least some of the time.

According to the PAM, perceptual difficulty arises as the result of L2 contrasts being assimilated to a single L1 phonological category. To this end, it was predicted that the two English contrasts /ɪ/-/i/ and /ɑ/-/æ/ would pose problems as previous studies on Spanish speakers have demonstrated a tendency for members of these contrasts to be assimilated to a single phonological Spanish category (Casillas & Simonet, 2015; Escudero & Boersma, 2004). Moreover, bilingual speakers have also been shown to display asymmetries in processing in contrasts that are present in only one of their languages (Casillas & Simonet, 2015; Escudero & Boersma, 2004). Thus, we sought to examine the status of these two contrasts in the processing system of Spanish-English bilinguals. Upon investigating the contrasts, we found that English and Spanish speaking bilinguals as a group did not process the /ɪ/-/i/ contrast to the same extent

as the control condition. However, variation in the processing of the /ɑ/-/æ/ contrast was not significantly different than that found in the control condition. That is to say, our results suggest that extensive experience with the /ɪ/-/i/ contrast does not imply that listeners will be able to process it as efficiently as other contrasts such as /ɑ/-/æ/ or the control contrast of /ɛ/-/u/, which would appear to be at odds with the extensive findings that demonstrate dominance to be a common influence on linguistic performance, including processing (see Casillas & Simonet, 2015; Escudero & Boersma, 2004; Kim & Repiso-Puigdelliura, 2019; Ortín, 2022, among others). Furthermore, the /ɑ/-/æ/ contrast appears to be inherently easier for listeners to process, allowing for the development of separate phonological categories for each member of the contrast.

Previous studies have demonstrated that language dominance is capable of influencing linguistic behavior in bilinguals (Amengual & Chamorro, 2015; Bosch & Ramon-Casas, 2011; de la Fuente Iglesias & Perez Castillejo, 2019; Piccinini & Arvaniti, 2018; Shea, 2019). As far as the present study is concerned, a correlation between dominance and processing was found only for the /ɑ/-/æ/ contrast: as participants' dominance in English increased, so did their accuracy in processing the /ɑ/-/æ/ contrast. While no correlation between dominance and processing was found for the /ɪ/-/i/ contrast, this contrast also yielded more errors than the /ɑ/-/æ/ contrast and control contrast of /ɛ/-/u/. This suggests that participants' accuracy in processing the /ɪ/-/i/ contrast is not associated with dominance as it remains unaffected by changes in dominance scores (at least in our data), and that it is possible for dominance to influence the formation of only some phonological categories.

This study sought to examine the effectiveness in the processing of the English contrasts /ɪ/-/i/ and /ɑ/-/æ/ among bilingual English and Spanish speakers and asked if the processing of

these contrasts was affected by language dominance. To do so, we made use of a sequence recall task, administered to English-Spanish bilingual undergraduate students in an institution with a sizeable bilingual community. Ultimately, it was found that language dominance only appeared to have an effect on processing of the /ɑ/-/æ/ contrast. Participants were equally efficient in processing the control contrast and other experimental contrast of /ɑ/-/æ/. That is to say, phonological categories held stronger for the /ɑ/-/æ/ contrast than for the /ɪ/-/i/ contrast, with the /ɑ/-/æ/ contrast showing more influence from dominance than the /ɪ/-/i/.

It must be noted however that the study and its findings are not without its limitations, due largely to the obstacles that were encountered carrying out the experiment and the small sample size that resulted from them. For example, difficulty in acquiring hardware capable of running the experiment and the time it took for participants to complete the experiment made it difficult to recruit a larger number of participants within the time constraints for this study. With a larger sample size there may have been greater differences between the processing of the experimental contrasts, and it could be better assessed if dominance truly does or does not influence the processing of the /ɪ/-/i/ contrast. To accommodate this, future versions of this study must employ the use of additional computers capable of running the experiment, so that multiple participants can participate at once, or if funding is available, convert the experiment to an online version (which requires payment per participant) so that it can be run on more devices than we may have on hand. At the very least, having a greater window of time to collect responses would also allow for a greater sample size, even if resources remain similarly limited as they were for this study.

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# APPENDIX A

# APPENDIX A

## TEXT OF BILINGUAL LANGUAGE PROFILE QUESTIONAIRRE USED

Bilingual Language Profile: English-Spanish

We would like to ask you to help us by answering the following questions concerning your language history, use, proficiency, and attitudes. This survey was constructed with support from the Center for Open Educational Resources and Language Learning at the University of Texas. The survey consists of 19 questions and will take less than 10 minutes to complete. This is not a test, so there are no right or wrong answers. Please answer every question and give your answers sincerely, as only this will guarantee the success of the investigation.

Thank you very much for your help.

Please click continue to begin.

I. Biographical Information

1. Participant number
2. Age
3. Sex
    - M
    - F
4. Current place of residence: City/State
5. Current place of residence: Country
6. Highest level of formal education
    - Less than high school
    - High school
    - Some college
    - College (B.A., B.S.)
    - Some graduate school
    - Masters
    - PhD / MD / JD
    - Other

II. Language History

In this section, we would like you to answer some factual questions about your language history.

Please answer each question by selecting the appropriate answer from the drop-down menu.

7. At what age did you start learning ENGLISH?
8. At what age did you start learning SPANISH?
9. At what age did you start to feel comfortable using ENGLISH?
10. At what age did you start to feel comfortable using SPANISH?
11. How many years of classes (grammar, history, math, etc.) have you had in ENGLISH (primary school through university)?
12. How many years of classes (grammar, history, math, etc.) have you had in SPANISH (primary school through university)?
13. How many years have you spent in a country/region where ENGLISH is spoken?
14. How many years have you spent in a country/region where SPANISH is spoken?
15. How many years have you spent in a family where ENGLISH is spoken?
16. How many years have you spent in a family where SPANISH is spoken?
17. How many years have you spent in a work environment where ENGLISH is spoken?
18. How many years have you spent in a work environment where SPANISH is spoken?

III. Language use

In this section, we would like you to answer some questions about your language use.

Please answer each question by selecting the appropriate answer from the drop-down menu

19. In an average week, what percentage of the time do you use ENGLISH with friends?
20. In an average week, what percentage of the time do you use SPANISH with friends?
21. In an average week, what percentage of the time do you use OTHER LANGUAGES with friends?
22. In an average week, what percentage of the time do you use ENGLISH with family?
23. In an average week, what percentage of the time do you use SPANISH with family?
24. In an average week, what percentage of the time do you use OTHER LANGUAGES with family?
25. In an average week, what percentage of the time do you use ENGLISH at school/work?
26. In an average week, what percentage of the time do you use SPANISH at school/work?
27. In an average week, what percentage of the time do you use OTHER LANGUAGES at school/work?
28. When you talk to yourself, how often do you talk to yourself in ENGLISH?
29. When you talk to yourself, how often do you talk to yourself in SPANISH?
30. When you talk to yourself, how often do you talk to yourself in OTHER LANGUAGES?
31. When you count, how often do you count in ENGLISH?
32. When you count, how often do you count in SPANISH?
33. When you count, how often do you count in OTHER LANGUAGES?

IV. Language proficiency

In this section, we would like you to rate your language proficiency by giving marks from 0 to 6.

Please answer each question by clicking on the appropriate button

34. How well do you speak ENGLISH?
    - 0 – Not well at all
    - 1
    - 2

- 3
- 4
- 5
- 6 – Very well

35. How well do you speak SPANISH?
36. How well do you understand ENGLISH?
37. How well do you understand SPANISH?
38. How well do you read ENGLISH?
39. How well do you read SPANISH?
40. How well do you write ENGLISH?
41. How well do you write SPANISH?

V. Language attitudes

In this section, we would like you to respond to statements about language attitudes by giving marks from 0-6.

Please respond to each statement by clicking on the appropriate button

42. I feel like myself when I speak ENGLISH.
    - 0 – Disagree
    - 1
    - 2
    - 3
    - 4
    - 5
    - 6 – Agree
43. I feel like myself when I speak SPANISH.
44. I identify with an ENGLISH-speaking culture.
45. I identify with a SPANISH-speaking culture.
46. It is important to me to use (or eventually use) ENGLISH like a native speaker.
47. It is important to me to use (or eventually use) SPANISH like a native speaker.
48. I want others to think I am a native speaker of ENGLISH.
49. I want others to think I am a native speaker of SPANISH.

# APPENDIX B

# APPENDIX B

## TRANSCRIPT OF TOKENS USED FOR SEQUENCE RECALL TASK

The exact order the tokens were presented in varied for each participant, but below are the transcriptions of the tokens for each sequence (2, 4, 6). Transcriptions are not provided for the practice trials since the tokens consisted only of recordings of a single non-word, though the order of the tokens was also randomized for each participant in the practice trials.

Control contrast: /u/-/ɛ/

1 = /’tɛgəl/
2 = /’tugəl/

Sequence of 2:

1. /’tɛgəl/ /’tɛgəl/
2. /’tɛgəl/ /’tugəl/
3. /’tugəl/ /’tɛgəl/
4. /’tugəl/ /’tugəl/
5. /’tɛgəl/ /’tɛgəl/
6. /’tɛgəl/ /’tugəl/
7. /’tugəl/ /’tɛgəl/
8. /’tugəl/ /’tugəl/

Sequence of 4:

1. /’tɛgəl/ /’tugəl/ /’tugəl/ /’tɛgəl/
2. /’tugəl/ /’tɛgəl/ /’tɛgəl/ /’tɛgəl/
3. /’tugəl/ /’tɛgəl/ /’tɛgəl/ /’tugəl/
4. /’tugəl/ /’tɛgəl/ /’tugəl/ /’tugəl/
5. /’tugəl/ /’tugəl/ /’tɛgəl/ /’tugəl/
6. /’tɛgəl/ /’tɛgəl/ /’tugəl/ /’tɛgəl/
7. /’tɛgəl/ /’tɛgəl/ /’tugəl/ /’tugəl/
8. /’tɛgəl/ /’tugəl/ /’tɛgəl/ /’tɛgəl/

Sequence of 6:

1. /’tɛgəl/ /’tɛgəl/ /’tugəl/ /’tɛgəl/ /’tugəl/ /’tɛgəl/
2. /’tɛgəl/ /’tɛgəl/ /’tugəl/ /’tugəl/ /’tɛgəl/ /’tugəl/
3. /’tɛgəl/ /’tugəl/ /’tɛgəl/ /’tɛgəl/ /’tɛgəl/ /’tugəl/
4. /’tɛgəl/ /’tugəl/ /’tugəl/ /’tɛgəl/ /’tugəl/ /’tɛgəl/
5. /’tugəl/ /’tɛgəl/ /’tɛgəl/ /’tugəl/ /’tugəl/ /’tɛgəl/

6. /’tugəl/ /’tɛgəl/ /’tugəl/ /’tɛgəl/ /’tɛgəl/ /’tugəl/
7. /’tugəl/ /’tugəl/ /’tɛgəl/ /’tugəl/ /’tɛgəl/ /’tugəl/
8. /’tugəl/ /’tugəl/ /’tugəl/ /’tɛgəl/ /’tugəl/ /’tɛgəl/

Experiment Contrast 1: /ɪ/-/i/

1 = /’tibən/

2 = /’tɪbən/

Sequence of 2:

1. /’tibən/ /’tibən/
2. /’tibən/ /’tɪbən/
3. /’tɪbən/ /’tibən/
4. /’tɪbən/ /’tɪbən/
5. /’tibən/ /’tibən/
6. /’tibən/ /’tɪbən/
7. /’tɪbən/ /’tibən/
8. /’tɪbən/ /’tɪbən/

Sequence of 4:

1. /’tibən/ /’tɪbən/ /’tɪbən/ /’tibən/
2. /’tɪbən/ /’tibən/ /’tibən/ /’tibən/
3. /’tɪbən/ /’tibən/ /’tibən/ /’tɪbən/
4. /’tɪbən/ /’tibən/ /’tɪbən/ /’tɪbən/
5. /’tɪbən/ /’tɪbən/ /’tibən/ /’tɪbən/
6. /’tibən/ /’tibən/ /’tɪbən/ /’tibən/
7. /’tibən/ /’tibən/ /’tɪbən/ /’tɪbən/
8. /’tibən/ /’tɪbən/ /’tibən/ /’tibən/

Sequence of 6:

1. /’tibən/ /’tibən/ /’tɪbən/ /’tibən/ /’tɪbən/ /’tibən/
2. /’tibən/ /’tibən/ /’tɪbən/ /’tɪbən/ /’tibən/ /’tɪbən/
3. /’tibən/ /’tɪbən/ /’tibən/ /’tibən/ /’tibən/ /’tɪbən/
4. /’tibən/ /’tɪbən/ /’tɪbən/ /’tibən/ /’tɪbən/ /’tibən/
5. /’tɪbən/ /’tibən/ /’tibən/ /’tɪbən/ /’tɪbən/ /’tibən/
6. /’tɪbən/ /’tibən/ /’tɪbən/ /’tibən/ /’tibən/ /’tɪbən/
7. /’tɪbən/ /’tɪbən/ /’tibən/ /’tɪbən/ /’tibən/ /’tɪbən/
8. /’tɪbən/ /’tɪbən/ /’tɪbən/ /’tibən/ /’tɪbən/ /’tibən/

Experimental Contrast 2:

1 = /’pægəl/

2 = /’pɑgəl/

Sequence of 2:

1. /’pægəl/ /’pægəl/
2. /’pægəl/ /’pɑgəl/
3. /’pɑgəl/ /’pægəl/
4. /’pɑgəl/ /’pɑgəl/
5. /’pægəl/ /’pægəl/
6. /’pægəl/ /’pɑgəl/
7. /’pɑgəl/ /’pægəl/
8. /’pɑgəl/ /’pɑgəl/

Sequence of 4:

1. /’pægəl/ /’pɑgəl/ /’pɑgəl/ /’pægəl/
2. /’pɑgəl/ /’pægəl/ /’pægəl/ /’pægəl/
3. /’pɑgəl/ /’pægəl/ /’pægəl/ /’pɑgəl/
4. /’pɑgəl/ /’pægəl/ /’pɑgəl/ /’pɑgəl/
5. /’pɑgəl/ /’pɑgəl/ /’pægəl/ /’pɑgəl/
6. /’pægəl/ /’pægəl/ /’pɑgəl/ /’pægəl/
7. /’pægəl/ /’pægəl/ /’pɑgəl/ /’pɑgəl/
8. /’pægəl/ /’pɑgəl/ /’pægəl/ /’pægəl/

Sequence of 6:

1. /’pægəl/ /’pægəl/ /’pɑgəl/ /’pægəl/ /’pɑgəl/ /’pægəl/
2. /’pægəl/ /’pægəl/ /’pɑgəl/ /’pɑgəl/ /’pægəl/ /’pɑgəl/
3. /’pægəl/ /’pɑgəl/ /’pægəl/ /’pægəl/ /’pægəl/ /’pɑgəl/
4. /’pægəl/ /’pɑgəl/ /’pɑgəl/ /’pægəl/ /’pɑgəl/ /’pægəl/
5. /’pɑgəl/ /’pægəl/ /’pægəl/ /’pɑgəl/ /’pɑgəl/ /’pægəl/
6. /’pɑgəl/ /’pægəl/ /’pɑgəl/ /’pægəl/ /’pægəl/ /’pɑgəl/
7. /’pɑgəl/ /’pɑgəl/ /’pægəl/ /’pɑgəl/ /’pægəl/ /’pɑgəl/
8. /’pɑgəl/ /’pɑgəl/ /’pɑgəl/ /’pægəl/ /’pɑgəl/ /’pægəl/

# BIOGRAPHICAL SKETCH

Elizabeth M. Garza ("Lizzy") was born and raised in McAllen, Texas. She graduated Summa Cum Laude from the University of Texas Rio Grande Valley in May of 2021, with her B.A. in English (Linguistics concentration) and two minors in English as a Second Language Instruction and Art. She earned her M.A., once again in English with a Linguistics concentration, from the University of Texas Rio Grande Valley in May 2023. In her time as an undergraduate and graduate student she has contributed to research projects such as UTRGV's Corpus Bilinguüe del Valle (CoBiVa) and received awards and scholarships from UTRGV such as the Engaged Scholar Award, Presidential Scholarship, and Presidential Research Fellowship. She has also tutored and taught undergraduate courses at UTRGV such as English Grammar and Rhetoric and Composition II. She can be reached at emgarza00@gmail.com.