NEUROPHYSIOLOGICAL INDICES OF THE EFFECT OF COGNATES ON VOWEL PERCEPTION IN LATE SPANISH-ENGLISH BILINGUALS

by

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Abstract

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The field of research in bilingualism and second language (L2) acquisition has yielded overwhelming evidence that acquiring a second language later in life will result in less accurate production and perception of consonants and vowels in the second language. These effects, in part, are a result of interference from the already formed phonetic categories shaped by early exposure to the L1 (Iverson, 2007). Phonetic categories from the L2 will, at least initially, be mapped onto phonetic categories from the L1 (Flege, 1995). Shared storage of similar lexical items from L1 and L2 may also take place resulting in differences in processing for words with similar meanings in both languages with similar meanings. Language learners of any age are able to acquire a limitless number of new vocabulary items in their L2. Whether similarities in orthography and/or phonology of semantically similar words affect access to and comprehension of these new L2 lexical items is still unclear. Another question is whether lexical items that differ only in a non-native sound contrast are processed as good or poor exemplars of the L2 word, as a poor exemplar of the L1 word, or as allophonic variation of the L2 word.

In this dissertation neural correlates of L2 words that have or do not have L1 cognates were examined. A group of monolingual English speakers and a group of late Spanish-English bilinguals were asked to decide whether pairs of cognate and non-cognate words were produced the same or differently. Words were pronounced in Standard English or with a change in the production of the stressed vowel in the word to a vowel more similar to a Spanish phoneme. The results revealed that cognate words seemed to facilitate L2 speech discrimination as evidenced by similar responses by bilinguals and monolinguals to these words and smaller or absent responses by bilingual participants to non-cognate words. This facilitation was in the form of a positive ERP response elicited by the frontal electrodes. These results provide a better understanding of why there are mispronunciations and misperceptions of lexical items in an L2 and how shared meaning influences these processes.

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1. Introduction/Review of the Literature

1a. The Critical Period for Second Language Acquisition

Considerable research suggests that there is an inverse relationship between the age of onset of the second language (L2) exposure and ultimate success in the precise perception and production of L2 speech sounds (Oyama, 1976, Flege, 1995). The basis of this problem has been characterized by various theories, with some positing a ‘critical period’ based on diminished brain plasticity due to cerebral lateralization (Lenneberg, 1967). Although many areas of linguistic development can be acquired to a native-like standard including lexicon and syntax, phonology is typically the area of lowest achievement and greatest frustration in late bilinguals (Scovel, 1969; 1988). It may be that loss of neuroplasticity makes it difficult to learn new behavioral and neuromuscular patterns that would be required for production of non-native speech sounds and speech sound patterns (Scovel, 1969; 1988.) Bialystok (1997) suggests that as a new language is acquired, children are more likely to form new sound categories, while adults, having more stabilized perceptual systems, will more likely assimilate new speech sounds into their L1 categories. A select few adult learners have challenged the idea of a critical period by showing high proficiency for late learners, surpassing expectations and eventually reaching the level of being indistinguishable from native speakers in their L2 for all areas of language development (Bongaerts, Mennen, & Van der Slik, 2000, Moyer, 1999). However, this is an extraordinary accomplishment and not the norm for late bilingual speakers. Cases where a late-bilingual reaches native-like attainment of L2 phonology are rare and do not accurately represent late-bilinguals as a whole.

Three major studies demonstrated a significant negative correlation between age of acquisition and ultimate proficiency in L2 learning, with other factors such as length of residence not accounting for this variance in abilities (Asher & Garcia, 1969, Oyama 1976, & Patkowski, 1980). In a study of Italian immigrants learning English, subjects were recorded in their L2 reading a paragraph out loud and telling a story about a frightening moment in their life (Oyama, 1976). Native English listeners were then presented with 45second segments of the recording and asked to judge them on a 5 point scale, with 1 being no foreign accent and 5 representing a heavy foreign accent. Those subjects who had moved to New York before the age of 11 years, regardless of length of residence or motivation, were judged similarly to native English subjects. For the paragraph reading task, native subjects received a mean score of 1.0, the 6-10 years-old age-of-acquisition (AOA) group received a mean score of 1.2, the 11-15 years AOA received a 2.27, and the 16-20 years AOA group received a mean score of 3.7. These findings suggested a strong effect of age of acquisition on perceived accentedness. Subjects with an age of arrival between 16 and 20 years of age were all identified as non-native and those with an age of arrival between 11-15 years performed with scores between the two other groups. It is possible that the difficulties of older learners in producing native-like speech in their L2 could be attributed to poor perception of these speech sounds. However, this study did not examine speech perception in these participants. Differences in performance on speech perception of L2 vowels between early and late bilinguals can also provide insight into the time frame of a critical or sensitive period for perceptual reorganization of speech sound categories, and how perceptual categories are initially formed.

The ability to perceive speech sound contrasts in an L2 is challenging and may never reach a native-like level, especially when that L2 is acquired later in life (Peltola et al., 2003). A decreased sensitivity to non-native sound contrasts appears to be present as early as 10-12 months of age (Cheour et al., 1998, Bosch & Sebastian-Galles, 2003, Polka & Werker, 1993, among others). Even early exposure to a L2 may not counteract the effects of the perceptual system established through early exposure to L1 and may result in poor discrimination of L2 speech sound contrasts (Sebastian-Galles, &Soto- Franco, 1999.)

In regards to the lexicon, late L2 learners demonstrate a higher level of proficiency when presented with words in their L2 that have similar equivalents in L1 (De Bleser et al, 2003, de Groot & Nas, 1991.) A language that has a greater number of similar words (cognates) rather than a larger number of dissimilar words, would therefore pose less of a challenge for a L2 learner, at least when acquiring a basic vocabulary.

1b. Cognates

Cognates, or interlingual homophones (and for some homographs) have a variety of definitions that focus more distinctly on the words' similarities in the areas of orthography, semantics, or phonology across two comparative languages. All definitions agree that they are words that have a shared meaning and origin and similar phonology across the two languages. Considerable research suggests that cognates often assist a person in vocabulary acquisition (de Groot & Nas, 1991 & Sanchez-Casas, Davis, & Garcia-Albea, 1992). Use of a masked-priming design where words were primed by an identical word, a cognate, or a non-cognate resulted in similar priming effects for identical words and cognates with non-cognate paired words demonstrating little to no effect (de Groot & Nas, 1991).

Words that have an L1 cognate equivalent facilitate processing for the L2 learner by allowing a faster processing route via either semantic or phonological similarities to the L1 word (Gollan & Acenas, 2004, Dijkstra, Grainger, & van Heuven, 1999, Dijkstra, Miwa, Brummelhuis, Sappeli, & Badyan, 2010). For example, using a picture naming task, bilingual Spanish-English participants demonstrated shorter naming times and less tip-of-the-tongue states when the pictures presented were words that shared a cognate in L1 and L2 (Gollan & Acenas, 2004). Cognates have shown a consistent advantage during lexical decision tasks in the L2 when a cognate shares orthographic and semantic similarities (Dijkstra, Grainger, & van Heuven, 1999). In this study, when presented with English words that were similar in either semantic relations, orthography, and/or phonology, Dutch native speakers demonstrated faster reaction times during a lexical decision task when cognates with a similar semantic relation and orthography were presented rather than control words or words that only shared phonological similarities. Dijkstra and colleagues suggest that each time a word is accessed its translation equivalent is also accessed, placing cognates of both languages equally at a lower threshold for retrieval activation than non-cognates. This phenomenon does not appear to work bi-directionally as activation of an L2 word form does not appear to be in parallel when a listener is initially presented with the L1 word form (Weber & Cutler, 2004.)

Although at the lexical level, cognates may be useful for more rapid lexical acquisition due to their orthographic similarity, they may be more challenging to produce with appropriate L2 phonology than a word that does not have a cognate equivalent (Derwing, 2003). If L1 and L2 cognate word forms are activated in parallel due to their phonological similarities, an L2 learner may access both L1 semantic and phonological representations. This can cause mispronunciations and intelligibility issues for the listener during production. For words that differ only in an L2 vowel change, less accurate comprehension when listening in their L2 may also occur, especially when the context has insufficient semantic information to select between minimal pair words.

Many late-bilinguals are highly efficient communicators although lack of sensitivity to L2 sound contrasts remains, even after many years of use in the L2 (see e.g., Pallier et al., 2001; Sebastián-Gallés & Bosch, 2003). Studies indicate that both languages of a bilingual are accessed when a word with similar orthography but dissimilar phonology across both languages is presented (Schwartz, Kroll, & Diaz, 2007). The non-selective nature of lexical access in bilinguals could result in production of an L2 cognate in a more L1-like manner if these words are stored as (or perceived) as homophones. Specifically, L2 phonemes may be perceptually assimilated into L1 categories for words that have L1 cognates making the 2 words indistinguishable.

1bi. Cognate Processing

A number of studies suggest that L2 words that have L1 cognates share lexical storage, but non-cognate words do not. This evidence emerges from studies showing similar activation patterns for the words of a cognate pair and absence of or minimal facilitory effects for non-cognates (Sanchez-Cases, et al, 1992). Specifically, words such as ‘elephant’ and its Spanish translation ‘elefante’ would share a lexical storage space in the brain, while the word ‘chair’ and its Spanish equivalent ‘silla’ would be stored separately, causing ‘chair’ to be more difficult or less likely to be accessed when the word ‘silla’ is presented. Due to the similarities in the phonological structures of ‘elephant’ and ‘elefante’ the activation of the two words together may cause confusion during the phonological selection stage of lexical retrieval, while ‘chair’ and ‘silla’ being phonologically dissimilar would not pose an issue with competing phonological activations.

When presented auditorily with cognate and non-cognate words in both their L1 and L2, Dutch-French bilinguals demonstrated similar brain activation for L2 cognates as for L1words that had or did not have cognate equivalents during a PET study (De Bleser, et al, 2003). When pictures of L2 non-cognates were presented and the participants were asked to silently name them, an increase in brain activation over that observed when cognates were presented was observed in the left inferior frontal and temporal parietal regions. The prefrontal cortex is thought to be activated in lexical selection among varying competitors and the left temporal cortex is activated in lexical retrieval (Thompson-Schill, D’Esposito, & Kan, 1999). Employment of both the left frontal and temporal regions suggests that their ability to retrieve L2 lexical items that did not have an L1 counterpart appears to be more challenging and requires recruitment of a larger area of brain regions. In contrast, more efficient semantic processing is thought to require less neural activity (Thompson-Schill, et al., 1999).

Priming designs have been used to assess the influence of cognate status on the time course of lexical activation in both L1 and L2. Sanchez-Casas, et al (1992) proposed that the extent of cross-language similarities between the prime and target words would either increase or decrease the amount of parallel activation of shared word forms across languages. Three conditions were used for both cognates and non-cognate words; a repetition condition, a cognate condition, and a phonologically similar non-word condition. All words were visually-presented in English, which was the L2 of the participants. They found a significant difference between the amount of co-activation of a word’s translation with respect to whether or not the word had a cognate equivalent in the L1.

1c. Models of Lexical Organization and Access

Speaking in an L2 is a process that begins with finding the translation equivalent of the word that has been chosen, then choosing a grammatically appropriate context to produce it in (if produced in a sentence), and finally accessing information regarding the speech sounds required to produce the word intelligibly according to L2 phonemic constructs. When a word (or node) is accessed, similar words are also activated and are used as options for lexical selection in a process called automatic spread of activation (Levelt, 1989). When a word such as ‘cat’ is accessed, other semantically related words may also be accessed such as, dog or whiskers. Once the correct node has been selected, the phonological segments of only the chosen node are then retrieved, so that /k/, /æ/, and /t/ will be activated (Levelt, 1989). In contrast, the cascading view of lexical selection suggests that all activated nodes (e.g., car, whiskers, etc.) will all send some portion of their phonological information (e.g., /kar/) to the selection process and therefore phonological information is activated before a final node selection is made (Carramazza, 1997 & Dell, 1997).

Current theories of bilingual lexical access make the assumption that lexical concepts are shared across the two languages (De Bot, 1992; Costa, Miozzo & Caramazza, 1999). Therefore, in the case of Spanish-English bilinguals, when ‘cat’ is accessed, then ‘gato’ may also be accessed due what these theorists call, “parallel activation of the two languages of a bilingual.” However, according to Levelt’s theory, once ‘cat’ is chosen as the target node, the phonological properties of competing words, such as, ‘gato’ or ‘dog’, will no longer be activated and the phonological properties of ‘cat’ will be exclusively activated. In contrast, according to Dell’s cascading view of lexical access, the phonological information from both L1 and L2 words will be spread throughout the lexical selection process (1997). This view can explain why L2 cognate words may be produced with a greater perceived accent than words without a cognate equivalent. One study demonstrated that when participants were asked if a phoneme was present in a target word, a non-present phoneme took longer to reject if it was present in the word's translation into the listener's other language (Colome, 2001). This suggests that lexical selection is not language specific and therefore phonological forms in both languages are activated. Another study demonstrated faster reaction times for cognates over non-cognates when L2 learners were asked to name pictures in either L1 or L2 (Costa, et al., 2000). This suggests that cognate equivalents are in a higher activation mode during lexical selection of the target concept than words that do not have a cognate equivalent.

1d. Factors in L2 proficiency

There are many factors that may affect a person's ability to gain native-like acquisition of a foreign language other than age of acquisition. Length of time living in a new country is one factor, although anything beyond two years was not found to be a factor in decreasing the presence of an accent (Flege, Munro, & Fox, 1993 & Munro, 1993). Other factors include social exposure to the language and environment, as many L2 learners who are immigrants to a new country often live in neighborhoods where it is not necessary to have proficient skills in the second language. Another factor is the amount of continued use of the L1 (Flege & MacKay, 2004). Another is the nature of the instruction environment for the second language. For example, if the L2 was studied in their native country, or if language study began in the L2 country they may have been exposed to different accents/proficiency levels in their instructors. If the second language was studied in their native country, the instructors may have provided a poor phonological example in the L2.

In conclusion, there are many factors that can affect a person's success in acquiring a new language. Phonology appears to be one of the most challenging areas of language acquisition for the late language learner. As discussed above there are patterns of acquisition and errors based on age at acquisition, nature of the native language, and other areas of exposure and environment. This study examined native Spanish speakers learning English as adults and will focus on words that are phonetically and semantically similar in English and Spanish and to determine whether phonetic similarity of words with similar versus different meanings across languages has a differential effect on perception of vowels that are not phonemic in the first language.

1e. Speech Perception in L2

1ei. Vowel Perception in L2

By one year of age, infants demonstrate sound perception that is clearly linked to their ambient language (Bosch & Sebastian-Galles, 2003, Rivera-Gaxiola, Silva-Pereya, & Kuhl, 2005 among others). Patterns of speech sound categorization that have been solidified after long term exposure to a language are hypothesized to be highly automatic. Strange describes this as involuntary language-specific phonetic perception in her Automatic Selective Perception (ASP) Model (Strange, 2006 & 2007). In this model, listeners are automatically selecting the phonetic features to which they will attend and these are called Selective Perceptual Routines (SPRs). These SPRs reflect language-specific weightings of particular features that will allow the recovery of the phoneme identity.

Sounds that are similar in a speaker's first and second languages can often cause confusion during acquisition. Two major theories have been proposed to explain the differences in native versus L2 speech perception and production. Both posit that non-native like sound productions are rooted in perceptual differences and that the perceived similarities and differences between the sound systems of a speaker's two languages play an important role. The Perceptual Assimilation Model (PAM) was extended to give a more comprehensive explanation of phonological learning patterns in L2 acquisition. PAM-L2 assumes that listeners will assimilate L2 sounds into L1 categories as either good or poor exemplars of the L1 sound (Best & Tyler, 2007). This theory was initially founded on consonant assimilation patterns, but similar assimilation patterns have held true for vowel sounds (Levy & Strange, 2008). PAM-L2 assumes native-like discrimination patterns for an L2 contrast that is perceived as a phonological match to an L1 contrast. Therefore, an L2 contrast that contains two sounds that fall within two separate L1 categories will be more easily discriminated than two L2 speech sounds that fall within one L1 category, even if there is less physical difference between their realizations. Certain L2 vowel counterparts may never be acquired (either perceived or produced) in a native-like manner. If a vowel is perceived as simply a less accurate exemplar of an L1 vowel it may never form its own separate phonological category. Being a 'good' or 'bad' exemplar of a sound category, may allow for more accurate discrimination than two exemplars that fit equally well into one category. However, discrimination or categorization may still be poorer for the two contrasts than for two L2 speech sounds that fall into separate categories of the L1. PAM-L2 also suggests that some L2 speech sounds, those which are the most dissimilar to L1 sounds, will be uncategorizable and may not even be perceived as human speech, for examples clicks in certain African dialects. PAM-L2 also posits that the best time for phonological training in an

L2 occurs before extensive vocabulary acquisition. The frequency of a given word or phoneme and general patterns of assimilation based on language will determine how much exposure to a language will assist in improving L2 phonological perception and production (Strange & Shafer, 2008).

The Speech Learning Model (SLM) suggests that similar sounds will at least initially be assimilated into one vowel category. SLM also posits that the mechanisms that we used to learn our native language are in place throughout our lifetime and that with intense exposure to an L2, a new category may be formed in some cases (Flege, 1995). SLM proposes that these perceptual patterns that have been formed from extended experience with one's native language are the cause for difficulties in learning L2 phonology. This interference from L1 categories rather than maturational constraints or loss of neural plasticity, as suggested by the critical period hypothesis, underlie L2 perception difficulties. In this case, a large amount of similarity between two sounds in the L1 and L2 may initially impede the learner's ability to form a new perceptual category for this sound. A sound that is not considered a good fit into one of the previously formed categories will then be more likely to form its own category and with experience be produced more native-like than sounds that were assimilated into L1 categories.

A speaker's perceptual system is shaped by the phonemic repertoire of the L1 at early stages of development in a manner that will determine the perception of non-native phonemic contrasts, even if there is consistent exposure to L2 beginning at an early age (Sebastian-Galles, N. &Soto- Franco, S., 1999 & Sebastian-Galles, Echeviarria, & Bosch, 2004). Proficient bilinguals of Catalan and Spanish demonstrated differential responses to words and non-words that differed in a vowel change that only existed in Catalan. Those bilinguals that were exposed primarily to Spanish when they were young and learned Catalan in school, did not consistently discriminate words which differed only in a vowel contrast that does not exist in their first language. These vowels were most likely processed as allophones and therefore these words and non-words were treated as homophones (Sebastian-Galles, N. &Soto- Franco, S., 1999 & Sebastian-Galles, Echeviarria, & Bosch, 2004). Results from this study suggest that experience with a language did not assist in creating a 'new' vowel category for this sound, but rather it was most likely processed as PAM suggests as an exemplar of a similar L1 vowel category.

1eii. Cross-language effects in speech perception

The degree to which new vowel contrasts are acquired is highly dependent on the age at which the L2 is acquired (Baker & Trofimovich, 2005). Similarities and differences in the sound systems of the two phonological systems may also be a factor in differential speech sound categorization (e.g., Flege, Bohn, & Jang, 1997, Flege, Munro, & Fox, 1994, Strange, et al., 1998). For example, Flege and colleagues (1997) found that experienced and inexperienced learners of English from four different language backgrounds showed differences in discriminating English vowel contrasts, related to experience and language background. Overall, experienced learners performed more accurately than inexperienced learners in their ability to discriminate vowel contrasts in their L2. Spanish learners were better than German, Korean, or Mandarin learners of English when distinguishing /æ/ and /ε/. In contrast, the German learners of English performed better than the other three language groups when asked to discriminate the /i/ from the /I/ phoneme.

Vowels are often responsible for carrying a significant load of word meaning, and difficulty discriminating vowels at the word level may result in misunderstanding of the message and a high level of frustration to the second language learner. The English vowel system is large compared to other languages and many vowels differ by a relatively small spectral change. English unstressed vowels are often reduced, especially in conversational speech and therefore formants and other spectral cues do not remain consistent across contexts (Borden, 2003). A speaker's perception of vowels and their ability to generate vowels in their second language in a manner that makes them intelligible to listeners and perceptually distinguishable from each other is imperative to becoming an accurate communicator in an L2. English also has a variety of minimal pairs, or words that are visually and/or phonologically similar, which differ only in one phonological element (often a vowel). A number of small phonetic differences (eg,, /bæt/ vs. /bɛt/) found in English are not considered phonemic in Spanish and may be processed as homophones by Spanish late learners of English and share a single lexical representation.

Speakers of languages with larger vowel inventories produce vowels with more acoustic difference between them than speakers from languages with smaller vowel inventories as a product of their experience (Bradlow, 1995). Evidence from studies assessing the perception abilities of subjects from a language with a larger vowel inventory and a language with a smaller vowel inventory indicate that learning new vowels will be more challenging when one goes from having fewer vowel categories to a greater number of vowels (Hacquard, 1993.) Native speakers of French (which has a larger vowel inventory than Spanish) were observed to detect more minute changes in vowels when compared to native speakers of Spanish during an MEG study using vowels meant to sound native in both French and Spanish. The study used an oddball paradigm with a vowel native to both languages as the standard in each train of sounds presented. Based on these results vowel perception, at least in adults, is therefore language-specific and will impact a late-learners ability to acquire distinct phonemic aspects of a new language's phonology.

An example of how difficulty forming new vowel categories may affect a late Spanish-English bilingual, is that they may pronounce the word 'racket' with a more Spanish-like vowel pronunciation causing it to sound more like the word 'rocket', this same error could occur with the word 'battle' which when pronounced by a speaker with a Spanish background may be produced more like 'bottle.' A late Spanish-English bilingual may both perceive and produce these minimal pairs as homophones.

Although Spanish and English may share a similar alphabet and many similar word forms, their phonological repertoires is greatly different in the realm of vowels. The major difference between these two vowels systems is size. Whereas Spanish contains only 5 vowels, English has at least 11 distinct vowels (depending on the dialect). Spanish has one high front vowel, which is similar, but not identical to the English vowel /i/ as in "eat." English also has a second high front vowel, /I/ as in "bit," which does not have a phonemic counterpart in Spanish. Spanish has one mid-front vowel, which is similar, but not identical, to the English vowel /e/, as in "ate." English also contains a second mid-front lax vowel /ɛ/, as well as a low-front vowel, /æ/, as in the words "bet" and "cat" respectively. Lastly, Spanish has a low-central vowel, /a/ as in "hol<u>a</u>" and English has /ɑ/ as in "hot." These specific vowels will at least initially be perceived as a variant of one of the five Spanish vowels and be categorized into an existing vowel category by late learners of English (Fox, Flege, & Munro, 1995). We can hypothesize that a late Spanish-English bilinguals' perception and production of the English vowel /I/ will be close to their vowel /i/, while /ɛ/ will be close to the Spanish vowel /e/, and finally their perception and production of / æ/ will most likely fall acoustically somewhere between the English / æ/ and the Spanish /a/. Spanish speakers of English may also collapse the /ɛ/ and / æ/ phonemes into one category because Spanish has neither lax nor low front vowels (MacDonald, 1989). Spanish speakers typically produce lax vowels such as the three mentioned above, somewhere between the Spanish and English norms (Magen, 1998). Routine errors could include /kis/ for /kIs/ 'kiss', /bed/ for /bɛd/ 'bed', and /hat/ for /hæt/ 'hat'.

1eiii. Tasks Used to Assess Vowel Perception

The ability of the brain to reorganize its sound categories appears to decrease with age. Second language learners have demonstrated different levels of ability in perceiving L2 sound contrasts depending on the nature of the contrast and the memory demands of the task. In a simple auditory discrimination task in which the auditory memory load and cognitive support required are minimal and the acoustic signal is clear, even non-native listeners can perform in a native-like manner (Winkler, et al., 1999). Past research studies in speech sound perception have used various identification or discrimination tasks. Identification tasks ask the listeners to select a category label for a speech sound. The category label is often the orthographic symbol associated with the speech sound. This type of task can be difficult with second language learners, as they may not have a strong grasp of L2 orthography. This is especially difficult in languages such as English, in which the grapheme-phoneme relationship is often not transparent (letters do not correspond directly with one sound). Other tasks, such as using pictures to represent a word containing the target sound, have been used to mitigate this problem.

In contrast, discrimination tasks do not require listeners to remember the relationship between a symbol and a speech sounds. However, the memory load required for making the discrimination can be manipulated to make the task more or less challenging for the listener. For example, an increase in ISI will require the listener to access long term memory traces from their stored phonological categories, rather than using immediate recall of general acoustic information. A longer time between the auditory presentations of different words/sounds would demand that a listener use their long-term memory representations. In their L1, this would most likely not be problematic, but in an L2 they may not have formed accurate representations of the sounds presented in their long-term memory stores. When more than one token of a sound category is used and/or the time between presentations of sounds is extended, this can increase the difficulty of the task (McGuire, 2010). Increasing the ISI is thought to force the listener into a more 'phonemic' mode of speech perception and force them to use their experience based perceptual processes rather than simply analyzing sounds for their basic acoustic properties. Another way to increase the difficulty of the task is to include productions from more than one speaker, this will tax the listeners memory load further as they will have to account for not only acoustical and phonetic differences, but inter-speaker variation as well. When more than one exemplar of a sound is presented by different speakers, a listener will have to be able to parse out only the relevant changes in the sound in order to discriminate based on a phonetic change rather than a speaker change.

1eiii. Priming Studies

In order to examine the influence that the presentation of one stimulus has on a second or later occurring stimulus, recent studies have used a priming paradigm. This task is designed to tap into the fine-structure of lexical organization (see section above on lexical models). In this design an initial stimulus (called the prime) precedes a 'target' stimulus. Automatic spread of activation (Neely, 1977 & Levelt, 1989) and/or semantic expectancy will result in faster access of the target form, in the case that they are semantically-related. In the case that they are phonologically related, priming can lead to facilitation in production, but sometimes results in inhibition in access depending on the delay between the prime and the target. Thus priming effects are often apparent in the response time for a decision about the semantic or phonological properties of the target, and can also affect accuracy of the response.

A large number of studies has manipulated the relationship between the prime and target in terms of phonology, orthography, or semantics (Costa, Colome, & Caramazza, 2000). In terms of phonological priming, when the target stimulus is identical or similar to the prime stimulus, access to the target will be facilitated (Duyck, et al, 2004), but in the case where there is overlapping orthography this effect will decrease (Dimitropoulou, et al, 2011). When a priming method was used to examine the effect of a semantically similar word being used as a prime, results have demonstrated an inhibitory effect in participants' speed in naming a given picture (Costa, Miozzo, & Caramazza, 2000) although other studies have shown a facilitory effect when the words are related but not part of the same semantic category (Costa, et al, 2005.) Using a phonologically-similar prime in a picture-naming task facilitated naming speed (Costa, et al., 2000.)

In studies examining lexical semantic processing in the L2, one study found that both form (phonology) and meaning (semantics) had a faciliatory effect on lexical access to words in a second language (Sanchez-Casas, et al, 1992.) In contrast, increased phonological dissimilarity between the prime and target will result in less facilitation or possible inhibition of access to the target (Dijkstra, 1999). This method can be used to assess the sensitivity to minute changes in phonology between two stimuli. Specifically in L2 research, this method can be used to assess the sensitivity of the second language phonetic system in detection of changes in L2 words. By comparing the response to identical word repetition to words repeated with one specific attribute changed, we can gain knowledge regarding the strength or absence of a repetition response based on that change (Rugg, Doyle, & Wells, 1995).

1f. Electrophysiological correlates of lexical and phonological processing

Neurophysiological measures can be used to understand the nature of phonological and lexical perception in both monolinguals and bilinguals. Electrophyisiological methods have demonstrated sensitivity to cross-language vowel differences (Winkler, et al., 1999). In addition, event-related potentials (ERP) have also shown sensitivity to proficiency levels in second language acquisition (Ojima, Nakata, & Kakiji, 2005). ERPs are time sensitive and therefore can give us information regarding the order and timing of lexical processing. They can also provide general information regarding brain areas recruited for language processing. This information can assist us in understanding the differences in speed and areas of neural involvement between L1 and L2 processing. Use of a priming design in conjunction with ERPs can assist in understanding whether the effects of priming are at an early, more automatic level of processing, or at a later level of processing that is likely to require cognitive awareness. One measure that has been particularly useful in studying lexical processing is the ERP N400 component. The N400 is sensitive to lexical access factors, as well as factors reflecting integration of semantic information into a prior context. The N400 is a negative deflection that peaks between 200 and 600 ms after a target stimulus' onset and is observed over superior central and posterior scalp sites (Schoonbaert, et al, 2011). Studies suggest that increased difficulty in integrating a word (target) into a context (in this case the prime) leads to an increase in the N400 amplitude. A word that is preceded by an identical word will demonstrate relatively less negativity (N400) compared to a word that differs in semantic and/or phonological factors (Praamstra, et al., 1994;

Holcomb & Neville, 1990.) N400 modulation has been demonstrated using both visual and auditory stimuli (and cross-modal stimuli). Several studies have shown that a negativity similar to the N400 in topography can index the degree of phonological differene between a prime and target words that are semantically unrelated (Praamstra, et al., 1994; Friedrich, et al., 2009).

Differences between L1 and L2 processing have also been investigated using the N400 measure. Less proficient L2 learners demonstrate a delay in the onset of the N400 response, as well as an increased late negativity to written words in the L2 (Midgley et al., 2009). The latency of the N400 response for late-bilinguals was negatively correlated with language proficiency. That is, the N400 has an earlier onset in readers with higher L2 proficiency. The larger amplitude N400 suggested that a subject had to work harder to retrieve the lexical item in the incongruent condition (Holcomb, et al, 2002).

The N400 has also indexed the difficulty that bilinguals have in forming new vowel categories in their second language, and how this can cause lexical confusion between two words that differ only in an L2 vowel contrast (Sebastian-Galles, Rodriguez-Fornells, Diego-Bala, & Diaz, 2006.) Participants in this study were early bilinguals of either Catalan or Spanish dominance. The authors used words that differed only in a Catalan vowel contrast, with the Spanish dominant bilinguals demonstrating difficulty perceiving the vowel change. These results suggest that the contrasts included in the stimuli were stored as one vowel category for these bilinguals. If an L2 vowel contrast has been assimilated into one L1 vowel category (e.g., English /i/ and /I/ may be assimilated into Spanish /i/), words that differ only in this contrast may be perceived as identical lexical items, possibly as good or poor exemplars of that vowel category. Difficulty distinguishing these vowels would be demonstrated by absence of an increased negativity compared to a no-change condition (where an identical word was repeated).

This finding indicates that the N400 to a phonological contrast can be used to assess the effect of lexical familiarity on phonological perception of standard or atypical productions of non-native vowel contrasts.

A recent study that used pairs of L1/L2 non-cognate translation equivalents and unrelated words in English and French demonstrated that the N400 could be used to assess strength of associations between the words in the two languages (Schoonbaert, et al, 2011). This study presented an L1 word as either the prime or target and paired it with an L2 word. A greater N400 amplitude was observed when the target was an unrelated word rather than a translation equivalent. In addition, the peak latency of the negativity was earlier for translation pairs than for unrelated pairs. Greater N400 amplitude was observed in the L1 to L2 direction. The authors suggest that there are rapid semantic activations that take place after an L1 word is presented, which leads to priming of the L2 target word. This finding shows that both languages for bilinguals are activated regardless of the language of the prime word. However, the task design may have encouraged participants to access translation equivalents. The finding of greater N400 amplitude for a L2 target following an L1 prime, however, indicates that L2 may somewhat automatically result in access of the L1 translation equivalent, but the L2 is less activated in the case of L1 lexical access.

Some studies have also observed other ERP components to be modulated by lexical factors. Schoonbaert et al. (2011), found an earlier negativity (which they termed N250) that was smaller when L1 preceded L2 words. The N250 is a negative going wave that peaks at approximately 250 ms after stimulus onset and has a wide spread topography. This component is larger (more negative) when targets have less lexical similarities to their prime (Holcomb &

Grainger, 2006). The authors suggest that this effect arises from the L1 word associations that are primed by the L2 word.

Following the N400, a late positive component has also been revealed as a marker of the degree of difference between a prime and a target word. This component referred to as the late positive component (LPC) or P3b appears to reflect an evaluation process. This P3b component is largest over parietal electrodes sites and is thought to be related to the response a participants makes to the stimulus (e.g., a same/different behavioral response) rather than a reflection of processing the physical properties of the stimulus itself (Linden, 2005). The classic P3b component is typically elicited in an oddball design; however, the topography and timing of the response is similar to that found in a same/different discrimination design. We will use the term LPC to describe the pattern found in a same/different paradigm rather than P3b, since determining the relationship between the positivities elicited in these different designs is not a purpose of this dissertation. The LPC/P3b is larger to a more discriminable than a less discriminable stimulus (Rugg, 1990). The LPC/P3b also increases in latency as the task increases in difficulty (Linden, 2005).

A few studies have also observed a frontal central positivity that appears to be sensitive to phonetic differences between stimuli. Wagner and colleagues (2012) observed a larger frontocentral positivity to word pairs that differed, compared to those that were identical in English and Polish listeners for a phonotactic difference that could only be behaviorally discriminated by Polish listeners. This positivity may reflect an acoustic-phonetic level of processing, since it did not differ in relation to language experience. In a different design, use of ERPs to examine the effect of stimulus repetition has demonstrated an overall positive shift in the waveform in the 400-600 ms time-frame that increased as the time between the presentations of identical stimuli was decreased (Henson, Rylands, Ross, Vuilleumeir, & Rugg, 2004). In addition, a frontal positivity was also demonstrated to repetitions between 200-300 ms post stimulus that was also followed by a negative deflection (Henson, et al., 2004). Thus, decrease in this positivity may be due to refractoriness of the neural population receiving afferent input. In other words, fewer neurons fire to repetition of a stimulus but with increased time, the neurons recover.

1g. Overview/Purpose

The purpose of this study was to examine the effect of lexical and phonological similarity, as demonstrated by cognates, on phonological perception at the word level in late L2 learners of English with Spanish as a first language. The study was designed to examine whether the phonological relationship (cognate or non-cognate) between translation equivalents of the L1 and L2 influence phonological perception. A match-to-sample ERP paradigm was used to determine whether the late L2 learners had more difficulty discriminating changes in vowels in English words that have Spanish cognates compared to English words that do not have Spanish cognates. The following hypotheses were tested:

1h. Hypotheses

Predictions for this study are the following:

1. Monolingual participants will show excellent discrimination of word pairs differing in the pronunciation of the stressed vowel (e.g, /sɪstəm/ vs / sistəm/) in both cognate and non-cognate conditions compared to pairs that are identical (e.g., /sɪstəm/ vs /sɪstəm/). Access to the lexical representation of the target word will be facilitated in the case that the following word is

an identical or near identical match. When the target word does not match the phonological representation of the prime word, this will cause the monolinguals to reject this production as a native-language form. Discrimination will be seen as greater accuracy and larger negativity at posterior parietal sites (N400) and/or posterior parietal positivity (LPC) to the different than the same pairs. Specifically, a robust ERP response to the vowel change in both cognate and non-cognate trials is expected. These will be seen as similar amplitudes and latencies of the ERP components across conditions. Monolingual participants should show no differences in speed of detection (reaction times) of the differences for cognate and non-cognate pairs when asked whether the word is pronounced the same or differently. The N400 in this case would reflect increased activity accessing the lexical representation of the second word in the pair. The N400 has been shown to indicate the awareness of a phonological difference between two lexical items (Praamstra, et al., 1994).

Prediction 2: Based on current research, the most likely scenario for bilingual participants would be that a cognate word is processed as a more familiar word (due to its similarity to an L1 matched word) and therefore changes in this word may be noticed more easily than if the word was a non-cognate. Studies suggest that cognates are translated more easily and demonstrate earlier priming than non-cognates (de Groot & Nas, 1991). ERPs will show an earlier and larger difference to the cognate than non-cognate pairs. The alternative prediction for bilingual participants is that they will demonstrate a smaller and later N400 (or LPC) to cognate pairs, if it takes longer to perceive the difference in the cognate pairs. If the L2 word is perceived using L1 selective perceptual routines (SPRs), the participants may show no evidence of conscious perception of a difference (either in N400 or LPC). In this case, the cognate words forms may be merged into one lexical item in the bilingual's vocabulary.

Prediction 3: It is possible that the direction of presentation of the stimuli will influence processing. Previous studies have demonstrated that bilinguals will translate at a slower rate in the L2→L1 direction than in the L1→L2 direction when presented with non-cognate words (Sanchez-Casas, et al, 1992). This suggests that when standard words precede "accented" words in the non-cognate conditions, that processing may be slower or less accurate. Assuming that bilinguals have shared storage of cognate words, but not non-cognate words, a directionality effect should only be demonstrated in non-cognate trials and should have no effect on cognate trials.

Chapter 2: Method

2a. Participants

Participants included 15 native monolingual speakers of English and 15 late Spanish-English bilinguals between the ages of 19 and 42 years. English speakers were from the northeastern part of the United States. Spanish speaking participants were from a variety of Spanish-speaking countries and may speak varying dialects of Spanish. All bilingual subjects will have begun their exposure to English after the age of 14 years (Oyama, 1976). Participants who studied in English in their native country before the age of 14 were accepted if their teachers were not native speakers of American English and they did not reach a conversationally proficient level before the age of 14 years. Participants with a hearing loss and/or history of speech-language delay were excluded from the study.

2b. Stimuli

Stimuli include 29 Spanish-English cognates and 34 non-cognates. Two non-cognates and 4 cognate words were omitted from the experiment due to the quality of their recordings. Word frequencies can be seen in Appendix A. Table A1. All words were measured based on their occurrence in a set of 51 million words. Many words were common (e.g., the non-cognate *dinner* was observed 10, 336 times in 51 million words), while others were less frequent (e.g., the non-cognate *bracket* occurred only 32 times in 51 million words). There was not a significant difference between the frequencies of the cognate words and frequencies of the non-cognate words. Vowels occurred in stressed positions to maintain a full vowel quality. Cognates and non-cognates included the target stressed vowel occurring in either the first or second syllable of the words. Experimental stimuli included one of the three English front vowels that are not included in the vowel system of Spanish (i.e., /ɪ, ɛ, æ/).

Words were recorded in Standard American English, and again with a typical Spanish-influenced accent on the stressed vowel only. Piloting using highly proficient early Spanish-English bilinguals for creating the stimuli revealed that they had difficulty changing only the vowel in the word to a Spanish pronunciation due to the automatic nature of their L1. Therefore, a late bilingual English-Spanish speaker (the author C.A.T.) who learned Spanish starting at 24 years of age recorded the stimuli, due to her ability to control the changing only the target sound and not the word as a whole. The words were recorded in a carrier phrase to allow for natural speaking rates. Each word was produced four times. The two middle productions for each word were selected as the experiment stimuli because they maintained similar prosodic patterns and fundamental frequencies. Each word was edited from the carrier phrase. Stimuli were normalized using Sound Forge 8.0 to the peak amplitude of -7.00 dB. On 13 occasions the standard word production uses more than one token of the word presented in the experiment in same pairs. This allowed checking of whether participants were using acoustic differences alone to make the discriminations. Otherwise same pairs consisted of the identical production of the word. All words were measured for vowel onset time and second syllable onset time to allow for ERP time-locking to these events for later processing. Stimuli ranged in length from 517ms to 880ms. As all stimuli occur as targets in both same and different pairs, the duration range is not problematic. Word pairs include prime (1^{st}) word, followed by a target (2^{nd}) word.

2c. Design

The current study utilized a priming paradigm. Word pairs were comprised of four possible combinations, as shown in Table 1 and were dispersed randomly throughout each block (see Table 2 for mean occurrences). The four conditions are: A standard prime followed by a standard prime, a standard prime followed by an accented target, an accented prime followed by a standard target, and an accented prime followed by an accented target. Each condition was used with both cognate and non-cognate words. Pairs of stimuli were separated by an 800 ms ISI. This interval was chosen to allow for recovery of refractoriness of the neurons involved in auditory processing. Participants were allowed 1,500 ms after the target word to respond using the response box, but if they respond earlier, the next prime word was immediately presented.

Table 1. Word types and possible combinations for each trial are listed below. SAE= Standard American English, SPA= word with vowel changed to a more Spanish production. 1 & 2 represent different exemplars of the same word.

Word Type	Production Accent	Difference	Predictions/Hypotheses	Example
Cognate-Cognate	SAE1-SAE1, SAE1-SAE2, SAE2-SAE2	Same	Bilinguals and Monolinguals will perform in a similar fashion	System-system /sɪstɛm/-/sɪstɛm/
Cognate-Cognate	SAE1-SPA1, SAE1-SPA2, SAE2-SPA1, SPA2-SAE2	Different	Bilinguals will demonstrate a decreased N400 secondary to having shared lexical storage and not having fully primed with first word/ monolinguals will have larger N400 secondary to having to work harder to retrieve the lexical item	System-system /sɪstɛm/-/sistɛm/
Non-cognate-Non-cognate	SAE1-SAE1, SAE1-SAE2, SAE2-SAE2	Same	Bilinguals and Monolinguals will perform in a similar fashion	Sister-sister /sɪstɚ/-/sɪstɚ/
Non-cognate-Non-cognate	SAE1-SPA1, SAE1-SPA2, SAE2-SPA1, SPA2-SAE2	Different	Possible difference between language groups, but N400 still greater than to cognate pairs	Sister-sister /sɪstɚ/-/sistɚ/

Table 2. : Number of occurrences of each condition across all 800 trials after random selection.

Trial Type	**# of Occurrences**	**Mean Occurrences per block of 80**
Cognate-Cognate Same 2 standards words	89	14.72
Cognate –Cognate Same 2 Accented words	81	21.81
Cognate- Cognate Different with Standard First	83	16.18
Cognate- Cognate Different with Accented First	120	15.09
Non-Cognate-Non-Cognate Same 2 standard words	117	16.36
Non-Cognate-Non-Cognate Same 2 accented words	90	21.27
Non-Cognate-Non-Cognate Different Standard First	104	21.09
Non-Cognate-Non-Cognate Different Accented First	116	18.91
Total	800	

2d. Procedure

All participants first completed a pure tone hearing screening at 25 dB. Monolinguals subjects underwent receptive vocabulary testing using the Peabody Picture Vocabulary Test (PPVT) and a 20 question vocabulary test using words from the experiment. Bilingual subjects completed English language testing using the PPVT prior to ERP testing, to approximate vocabulary size in L2 (raw scores rather than standard scores will be used as this test was not meant to assess second language vocabulary) and after ERP testing, the TVIP was be completed formally for the late-bilinguals to assess their lexical knowledge in their native language. Before ERP testing began, the bilingual subjects were also asked to complete a language background questionnaire regarding their educational background and daily use of each language, complete a 15 question English grammar test, and complete a 20 question vocabulary test including the least frequent words that will be presented in the experiment.

Participants were then asked to sit in a sound proof room to begin electrophysiological testing lasting approximately 40 minutes. Before testing began, each participant's head was measured to determine the correct net size. The net was placed on the participant's head by the researcher and the area of hair underneath electrodes were separated and the skin softly rubbed with extra potassium chloride solution to ensure acceptable impedances (below 50 kOhms.) The participant was then seated in a comfortable chair in a sound attenuated room. Then the participant was given verbal and written instructions to complete the same/different task and a 12 trial practice test using actual stimuli from the experiment and providing the participant with visual feedback (i.e., 'correct' or 'incorrect' flashed on the screen immediately after they press the button). After the 12 trial practice, the researcher entered the testing room to ask if the participant had any questions. At this time, the monitor was changed from a screen that gives feedback to a screen that shows a large picture of a shape (e.g., heart, circle, cube) with a gray or dark colored background. These shapes were provided as a target to look at to reduce eye movement during the experiment. At the beginning of each new 80 trial block, the researcher manually changed the shape on the monitor. Blocks were presented randomly. Stimulus delivery was controlled by E-prime software. Participants completed 10 blocks (800 word pairs).

All participants took part in a behavioral experiment during the ERP study. The behavioral experiment required that the participant identify whether the words are pronounced the same, or whether one of the words in the pair is pronounced differently. Participants were instructed to hold one finger from the left hand over the '1' button and one finger from the right hand over the ‘5’ button to allow for immediate response. They were instructed to press ‘1’ if they thought the words were pronounced the same and to press ‘5’ if they thought the words were pronounced differently. They were asked to move as little as possible and blink as little as possible while the words are heard as there would be brief pauses in the experiment in between blocks. In each block of stimuli, approximately 50% were experimental word pairs using the 3 target vowels (/æ, ɛ, I/) having the ‘mispronounced’/accented word presented first in some of the pairs and second in the other pairs. The amount of occurrence of each vowel for each word type can be seen in Table 3. A decision was made to focus on trials with the accented word in the second position. For this reason trials with the accented word in the first position served as fillers and were included so that the participant would not develop an expectation of prime words always being pronounced correctly.

Table 3: List of number of items for each word type

Word Type	**/I/ words 1st Syllable**	**/I/ words 2nd syllable**	**/ɛ/ words 1st Syllable**	**/ɛ/ words 2nd syllable**	**/æ/ words 1st syllable**	**/æ/ words 2nd syllable**
Cognates	8	2	4	7	9	3
Non-Cognates	9	7	7	3	13	2
Total	17	9	11	10	21	5

2e. Analysis of Behavioral Data

A verbal fluency task was performed on the final ten participants in the bilingual group to gain another measure of their proficiency in their L2. A language background questionnaire was used to create a numerical account of the history of the participants' language use and exposure over the last few years. Participants were asked to rate their language exposure from 1-7 (one being only Spanish and seven being only English) in a variety of speaking and listening situations (e.g., with family, with co-workers, at the movies.) In this questionnaire, participants were also asked to rate their own proficiency in several aspects of language including an overall proficiency rating.

It was not appropriate to calculate standard scores for the bilingual participants for the English PPVT, because vocabulary items on this test are ordered from the earliest learned to later learned vocabulary. In addition, an English listener's score is based on the last item they master before failing eight items in sequence. Late bilinguals cannot be expected to acquire lexical items according to the same order as a native speaker. For this reason, performance for this group was calculated as a percent correct for responses between items 73-144 (a total of 72 items). These vocabulary items begin at the 8-9 year old age range and end at the 12-16 year old age range as expected by native English speakers. These words therefore would be general knowledge for all monolingual speakers and therefore known by the bilinguals, at least in their native language. Participants were presented with all items, even if they missed eight in a row. A twenty question vocabulary test was presented to all participants to familiarize both monolingual and bilingual participants with the words used in the experiment, because both common and less common words were used in the experimental word set.

Figure 1. Geodesics 64 channel net.

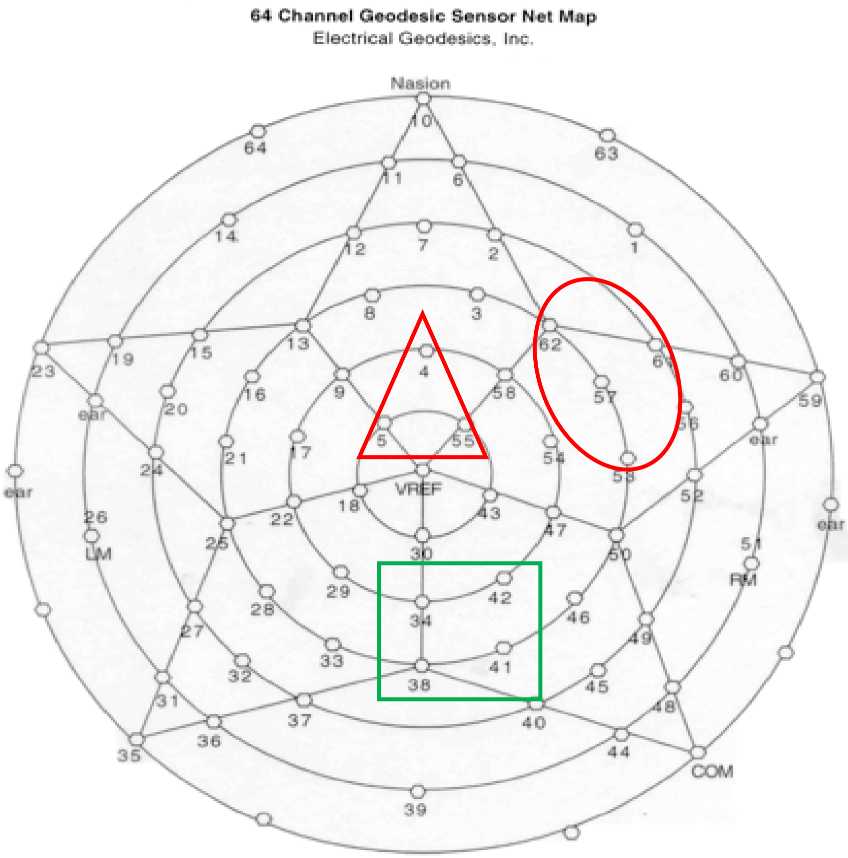


Figure 1. Map of eletrodes for Geodesics 64 channel net. Red lines show areas for frontal model electrodes (7) and green enclosure shows area for parietal model eletrodes (4).

2f. ERP Recording

The electroencephalogram was recorded at 250Hz sampling rate. A 64 channel Geodesics net was used (see Figure 1 for electrode locations.) The EEG was amplified using Geodesics amplifiers and a bandpass filter from 0.1-30Hz using. ERPs were time locked to the onset of the prime and target words, the onset of the target vowels in each word, and the onset of the second syllable for words where the target vowel was present in the second syllable.

2g. Data Analysis

Global Field Power (GFP) was used to extrapolate the times frames of interest related to the greatest areas of brain activity in the grand mean ERP waveforms time-locked to the onset of the target words. GFP calculates the standard deviations for all electrodes at each point in time, allowing for a reference free view of the time frames after the onset of the stimulus that resulted in the largest voltage change across electrodes.

Average waveforms were calculated for both the cognate and non-cognate condition. ERPs were averaged over 1000 ms epochs starting 200 ms prior to the onset of the target stimulus. Artifact rejection was set at +/- 100μV in more than 20% of the electrodes were rejected and excluded from averaging. Bad channels were removed and interpolated (replaced) manually using BESA software. Data was baseline corrected from -100 ms to 0 ms and re-referenced to an average reference. Analysis was completed by measuring the amplitude of the averaged waveforms at separate temporal intervals of 80 ms each starting from 200ms up to 800 ms post-stimulus onset (Schoonbaert, et al., 2011). These timeframes will allow for analysis of EEG activity during, as well as before and after the expected N400 response in addition to the LPC. Analysis of the fronto-central sites (Fz, 5, C6, 55, FC4, F8, F4) will be used to assess for the presence of the P400 component (see electrode placement in Fig. 1). Parietal electrodes (Pz, OPz, PO4, P2) were chosen as a particular area of interest as it has been demonstrated to include the N400 priming effect (Pickering, 2003). These electrodes were selected by completing a correlation analysis of all four condition types (e.g., bilingual cognates). Using site Pz as a center point, the other three electrodes chosen had a correlation of at least .8 with Pz and were correlated in at least three of the four condition types. These electrodes create a model of the overall response in the parietal region. Parietal electrodes were also used to examine the presence of the LPC in the time frames following 500ms.

To assess whether ERP component amplitudes were modulated by group, type, or condition, mixed-model regression analysis with a 2 x 2 x 2 factorial design was carried out with language group (monolingual or bilingual) as the between participant factor, word type (cognate/non-cognate), and condition (same/different) trials as within participant factors. Subject was used as a random effect and all other factors as fixed effects. Time frames of 80 ms were used and combined together with the following time frame if amplitudes were highly correlated.

Mixed-model regressions were completed for ERPs time-locked to the target word for same and different trials. The mean amplitude of components in each time interval were analyzed to assess for differences between groups, types, and conditions.

Chapter 3: Results

3a. Language Testing

This section includes results from both the behavioral and ERP portions of the experiment. Results from language testing and language background were used to assess relationships between language proficiency and use variables as predictors of ERP components. The ability to discriminate the same vs. different trials as well as the relationship between cognate status and speech discrimination are discussed for each language group.

Language testing results are shown in Table 4. All monolingual participants demonstrated a standard score within one standard deviation of the mean on the PPVT, indicating an age appropriate receptive vocabulary in English. Bilingual participants received standard scores of at least 100 on the TVIP, indicating age appropriate receptive language in their L1. Only one bilingual participant showed less than 85% accuracy on the experimental words (more than three words incorrect). This finding indicates that most participates had a general familiarity with the words presented in the study before arriving for the experiment.

Overall proficiency ratings in English ranged from four to seven, with most participants rating their L2 at a five or six. Recall that a rating of 7 was the highest. This pattern indicates a general proficiency in their L2 that is not far below their L1 proficiency, at least in their ability to use this language functionally.

Table 4. Proficiency measures for each of the bilingual participants on PPVT, word list, and fluency lists, age of acquisition (AOA), of English in years and their self-ratings.

Subject #	**AOA**	**PPVT Knowledge %**	**Self-rating of proficiency**	**Animals Fluency**	**Foods Fluency**	**Words list knowledge**	**Accuracy same/diff %**
57	16	0.87	5			18	0.83
61	31	0.87	6			19	0.75
62	25	0.72	6			15	0.71
63	22	0.9	5			18	0.85
64	36	0.87	5			19	0.85
67	21	0.92	5	16	21	18	0.89
69	25	0.92	6	20	29	20	0.90
70	28	0.9	5	19	29	19	0.70
71	17	0.9	5	18	29	17	0.93
72	21	0.89	6	16	22	19	0.84
74	18	0.86	4	19	21	18	0.57
76	14	0.89	6	20	27	20	0.91
77	18	0.82	7	11	24	18	0.85
78	16	0.87	7	17	17	19	0.81
79	23	0.71	5	12	15	17	0.89

Correlations were also undertaken using participant self-ratings, language use, and accuracy data to assess whether these measures of proficiency were related to language testing scores. No significant correlations were found between PPVT scores or the word fluency task score and a participant's self-rating, behavioral data accuracy (same/different) or their reported language use. Note that the variability in language measures is small across these participants, who are all proficient, and this suggests that significant correlations are less likely.

3b. Behavioral data from ERP experiment

Results from the same/different behavioral task completed during the ERP experiment were calculated by computing the number correct responses. Monolinguals showed a mean accuracy of 92% (SD=3.5%) and the bilinguals participants showed a mean accuracy of 82% (SD=9.7%). A two-tailed t-test of these values reveals a significant difference in the performance of the two groups (df = 14, $p=0.001$). When split into cognate and non-cognate categories (with same and different together), neither language group performed differently dependent on word type ($p=0.33$, t=0.1, df=13). When split into cognates and non-cognates, statistics were completed using only 14 bilingual participants, as the computer did not accurately collect one participant's data regarding type of word. A linear mixed model regression using binomial data was completed with the behavioral data with cognates and non-cognates trials as well as same/different trials being separated. The mixed model regression with Group, Type, and Condition as factors revealed main effects of Group, Type, and Condition (see Table 5). In addition there were significant interactions of Group x Type, Group x Condition, and Type x Condition, but no three-way interaction of Group x Type x Condition. This analysis revealed that Different trials provided more of a challenge to bilinguals than to monolinguals. The lowest accuracy score for an individual for different cognate trials was 43% and for different non-cognate trials it was 41%, and both of these low scores were from bilingual participants. For same trials, the lowest accuracy score for an individual for cognates was 75% and for non-cognates was 67%. Again a bilingual participant produced both of these low scores. It is of note that standard deviations for the bilingual group (see Tables 6 & 7) were larger than that of the monolingual group (see Tables 8 & 9). In addition, standard deviations for bilingual different trials were larger than those for same trials (Table 10a). A' prime transformations for the behavioral data are also displayed in Table 10b.

Table 5. Mixed model regression results for behavioral accuracy.

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	2.18087	0.15407	14.155	< 2e-16
Group	-0.93216	0.21442	-4.347	1.38e-05
Type	0.28478	0.08594	3.314	0.00092
Condition	0.43015	0.09593	4.484	7.33e-06
Group x Type	-0.32342	0.10593	-3.053	0.00227
Group x Condition	0.59831	0.12566	4.761	1.92e-06
Type x Condition	-0.23764	0.13441	-1.768	0.07705
Group x Type x Condition	0.16417	0.17290	0.950	0.34236

Behavioral data was then analyzed by examining hits and false alarms to calculate whether same or different trials were more accurately identified. There were significantly more misses (incorrectly identifying a different trial as same) than there were false alarms (incorrectly identifying a same trial as different) as seen in Table 6. T-tests indicate that these differences are significant and that same trials were responded to more accurately than different trials. Examination of the individuals' scores show that all but one bilingual participant showed this pattern. The monolingual participants also responded with greater accuracy for the same trials when compared to different trials (Table 8). There was a significant difference between monolingual and bilingual responses to same trials (df=27,t=4.04, $p=0.0014$) and to different trials (df=27, t=3.28, $p=0.0059$), with monolinguals consistently performing better than bilinguals. An F-test of the variance of behavioral accuracy was completed and revealed a significant difference between the variance of cognate Different trials between the two language groups (F(1,27)=12.8, *p<0.0001*). Non-cognate Different trials also demonstrated a significant differences in variance between the language groups (F(1,27)=9.14, *p<0.0001*). Variance of the Same condition was significantly different for the non-cognate trials (F(1,27)=9.31, *p<0.0001*) but not the cognate trials (F(1,27)=1.59, *p=1.99*).

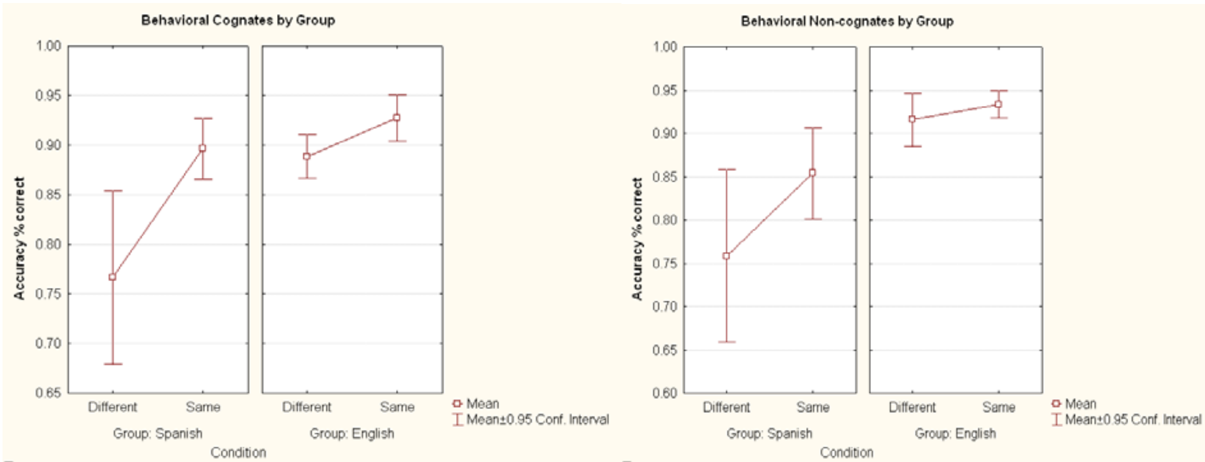


Figure 2: Behavioral data for cognates and non-cognates. Results from the bilingual group are on the left in both graphs.

Table 6. Behavioral data of bilinguals. Percent correct and total presented for Same and Different trials.

Subject #	%Diff correct	Total Diff	%Same correct	Total Same
57	0.77	382	0.90	338
62	0.50	382	0.95	338
63	0.82	424	0.89	376
64	0.81	383	0.89	336
67	0.86	431	0.93	369
69	0.87	424	0.94	376
70	0.54	426	0.88	374
71	0.93	424	0.88	376
72	0.75	424	0.93	376
74	0.42	382	0.74	338
76	0.91	426	0.90	376
77	0.82	424	0.89	376
78	0.79	431	0.83	369
79	0.89	424	0.88	376

Table 7. Results from t-tests of bilingual behavioral data.

Stats of t-tests	**Different Wrong #**	**Same Wrong #**	**Different Wrong %**	**Same Wrong %**
Mean	96.5	40.43	.88	.76
SD	61.88	17.78	.25	.16
SEM	16.54	4.75	.02	.02
N	14	14	14	14
P-value	*0.0032*		*0.0073*	
t-value	3.5864		3.1792	
df	13		13	

Table 8. Behavioral data from monolinguals. Percent correct for Same and Different trials and total number presented.

Subject #	%Diff correct	Total Diff	%Same correct	Total Same
17	0.957	425	0.968	375
21	0.96	423	0.95	375
25	0.91	424	0.917	376
26	0.905	425	0.938	373
28	0.89	425	0.965	375
29	0.908	425	0.96	375
30	0.959	424	0.965	376
31	0.92	391	0.94	375
32	0.876	375	0.908	372
33	0.83	424	0.859	376
34	0.877	417	0.9	383
35	0.95	427	0.96	373
36	0.87	426	0.903	373
37	0.899	417	0.89	383
38	0.9	421	0.889	379

Table 9. Results from t-tests of monolingual behavioral data.

Stats of t-tests	**Different Wrong %**	**Same Wrong %**
Mean	0.9074	0.92747
SD	0.03742	0.03461
SEM	0.00966	0.00894
N	15	15
P-value	*0.0055*	
t-value	3.27	
df	14	

Table 10a. Bilingual and monolingual subjects, percent accuracy results from behavioral testing.

Subject # Bilingual	Different cognates	Different non-cognates	Same Cognates	Same non-cognates	Subject # monos	Different cognates	Different non-cognates	Same Cognates	Same non-cognates
57	.78	.77	.88	.91	**17**	.93	.99	.96	.97
62	.49	.50	.97	.70	**21**	.96	.97	.96	.94
63	.81	.83	.90	.88	**25**	.89	.93	.90	.93
64	.81	.81	.89	.67	**26**	.92	.89	.93	.95
67	.88	.84	.93	.92	**28**	.84	.94	.98	.95
69	.86	.87	.95	.94	**29**	.90	.92	.97	.95
70	.59	.49	.88	.87	**30**	.95	.97	.98	.96
71	.89	.97	.94	.93	**31**	.90	.95	.93	.94
72	.79	.72	.92	.94	**32**	.85	.90	.88	.93
74	.43	.41	.75	.74	**33**	.85	.81	.87	.85
76	.89	.94	.92	.88	**34**	.85	.91	.91	.94
77	.83	.80	.86	.92	**35**	.92	.98	.98	.95
78	.78	.80	.88	.79	**36**	.86	.89	.89	.91
79	.90	.89	.90	.87	**37**	.90	.90	.86	.92
					38	.80	.80	.93	.94
Means	**.77**	**.76**	**.9**	**.85**		**.89**	**.92**	**.93**	**.93**
SD	**.15**	**.76**	**.05**	**.09**		**.03**	**.06**	**.04**	**.03**

Table 10b. A' prime table for behavioral data based on % accuracy.

Word Type	**Monolinguals**	**Bilinguals**	**t-value**	***p value***
Cognate	0.832	0.731	3.18	0.007
Non-cognate	0.862	0.716	4.36	0.0008

3c. Statistical Analysis of ERP results

Data were broken down into 80 ms time frames starting at 200 ms post-stimulus presentation and ending at 800 ms post-stimulus presentation (with a final frame of 40 ms). These time frames were further collapsed into 160 ms time frames (or 120 ms for the last two times) when two adjacent time windows were highly correlated. Two regions of interest were selected (frontal and parietal). The following sections will include information regarding early, middle, and late time frames along with statistics completed using Group, Type, and Condition as factors. The only results discussed in detail will be those where Condition was a significant effect or was part of a significant interaction. The effects of Group and Type are only considered interesting when they interact with Condition.

3d. Epochs 200-279ms and 280-359ms

3di. Parietal model

The early time frames that included 200 ms post stimulus onset up to 359 ms were analyzed for the presence of any early negativity related to the N400 component. Results of the analysis are presented in Table 11. Use of the parietal model electrodes revealed a main effect of Condition ($p<0.01$). The amplitude of the same trials (mean of -0.15 µV for English and -0.32 µV for Spanish group) was on average 0.3 µV less than the different trials (mean of 0.616 µV for English and 0.21 µV for the Spanish group). The condition effect indicated neural discrimination of the different pairs. A significant interaction of Group x Condition was also present in the 200 ms time frame with monolinguals demonstrating a greater difference between the same and different trials than found for the bilinguals. A significant three-way interaction was found between Group, Type, and Condition (*p=0.001*). Monolinguals and bilinguals in this time frame demonstrate similar responses to non-cognate stimuli (see Fig. 2b). In contrast, bilinguals demonstrate less recognition of the vowel change in cognate Different trials (see Fig. 3a).

Table 11. Mixed models results from parietal electrodes in the 200 & 280 ms time frames.

Parietal Electrodes 200 & 280 ms time frames	**Estimate**	**Std Error**	**t-value**	**Pr(>|t|)**
Group	-.16	.17	-.9	.36
Type	-.48	.03	-.13.2	.000**
Condition	-.3	.03	-8.3	.000**
Group x Type	.2	.05	3.9	.0001**
Group x Condition	.13	.05	2.6	.0075*
Group x Type x Condition	-.24	.07	-3.2	.0011*

**p<0.01*, ***p<0.001*

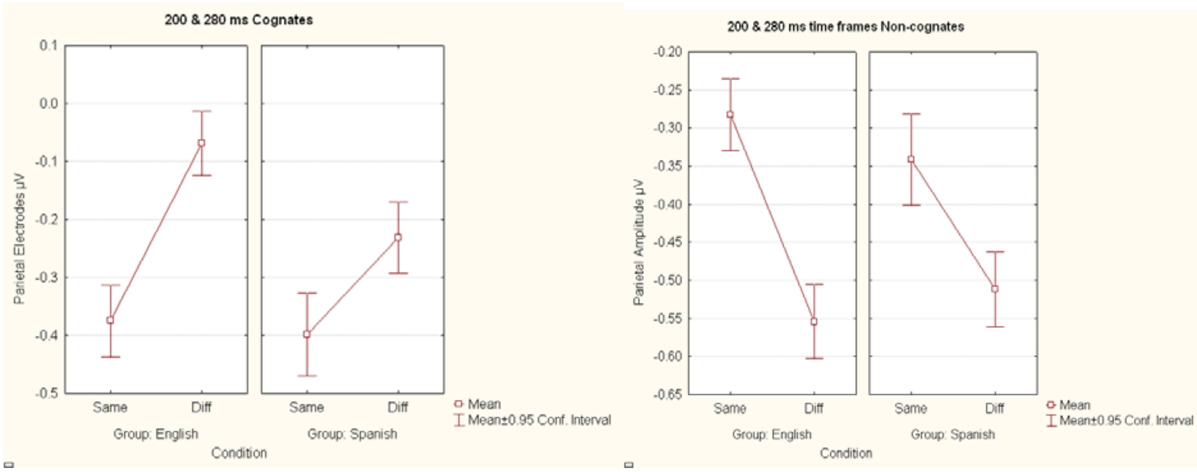


Figure 3a & b. (a) parietal amplitudes in the 200 & 280 ms time frames to cognates demonstrating a larger response by the monolingual group to Different trials. (b) parietal amplitudes in the 200 & 280 ms time frames to non-cognates demonstrating similar responses across language groups.

3dii. Frontal model

To determine the presence of a phonological mismatch/mapping negativity (PMN) an analysis was completed on ERP responses starting at 200 ms post-stimulus onset. Due to the high correlation ($r>0.8$) between these two time frames (between 200 and 359 ms) in the frontal region, they were collapsed into a 160 ms time window for statistical analysis. The PMN is thought to be an index of phonological awareness and may reflect early stages of word recognition; hence it could be expected in response to the vowel change in the target word during Different trials (Connolly & Phillips, 1994, Connolly, et. al., 1992). Results revealed a significant main effect of Condition as well as a significant interaction of Group x Condition (see Table 12 for statistics). Monolinguals demonstrated a more positive response to Different trials when compared to Same trials, while bilinguals demonstrated little to slightly negative responses to Different trials, especially for non-cognates, but this was statistically significant (see Fig. 4a & b). There was not a significant interaction of Group x Type x Condition ($p = 0.21$). This time frame reveals sensitivity to stimulus difference, but modulation by lexical type (cognate/non-cognate) is not yet observed. A PMN was not observed by either language group.

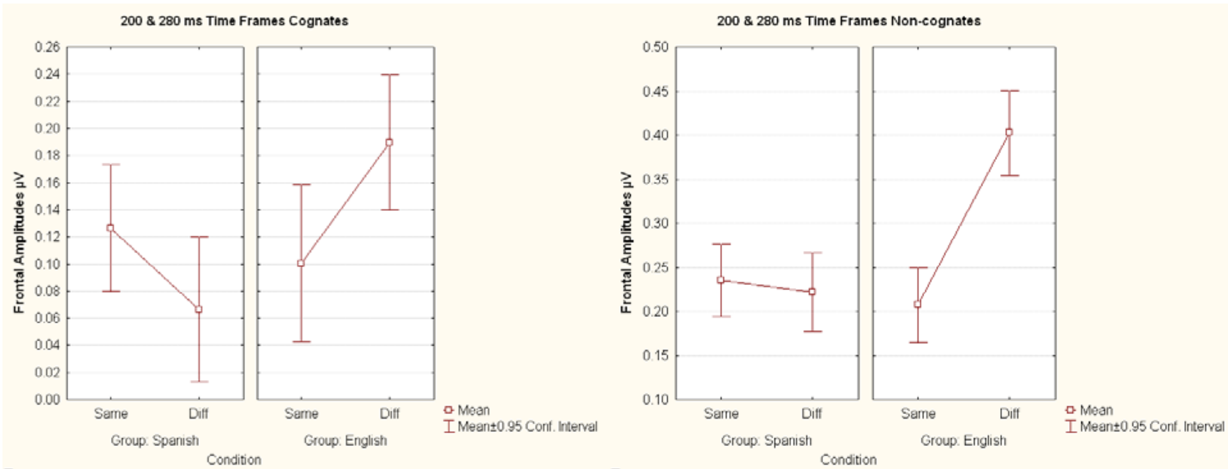


Figure 4a & b. (a) frontal model amplitudes in the 200 & 280 ms time frames to cognates showing monolingual participants with more positive responses to Different trials. (b) frontal model amplitudes in the 200 & 280 ms time frames to non-cognates, with bilinguals demonstrating less recognition of the vowel change than monolinguals.

Table 12. Mixed models results from frontal electrodes in the 200 & 280 ms time frames.

Frontal Electrodes 200 & 280 ms time frames	**Estimate**	**Std Error**	**t-value**	**Pr(>|t|)**
Group	-.123	.13	-.6	.51
Type	.212	.19	7.5	.000**
Condition	-.088	.028	-3.1	.0017*
Group x Type	-.057	.028	-1.4	.15
Group x Condition	.14	.04	3.7	.008*
Group x Type x Condition	.05	.056	1.05	.2921

**p*<.01, ***p*<.001*

3e. Epochs from 360ms-439ms and 440ms to 519 ms

3ei. Parietal

Table 13. Mixed models results for parietal electrodes in the 360 & 440 ms time frames.

Parietal Electrodes 360 & 440 ms time frames	**Estimate**		**Std Error**		**t-value**		**Pr(>|t|)**	
	360	**440**	**360**	**440**	**360**	**440**	**360**	**440**
Group	-.29	-.25	.31	.35	-.96	-.72	.34	.47
Type	-.41	-.32	.05	.05	-8.2	-6.5	.0000**	.0000**
Condition	.07	.15	.05	.05	1.49	3.01	.13	.003*
Group x Type	-.006	.24	.07	.07	-.09	3.49	.92	.0005**
Group x Condition	-.02	.11	.07	.07	-.34	1.63	.73	.102
Group x Type x Condition	.19	-.37	.09	.09	1.9	-3.7	.056	.0002**

**p*<.01, ***p*<.001*

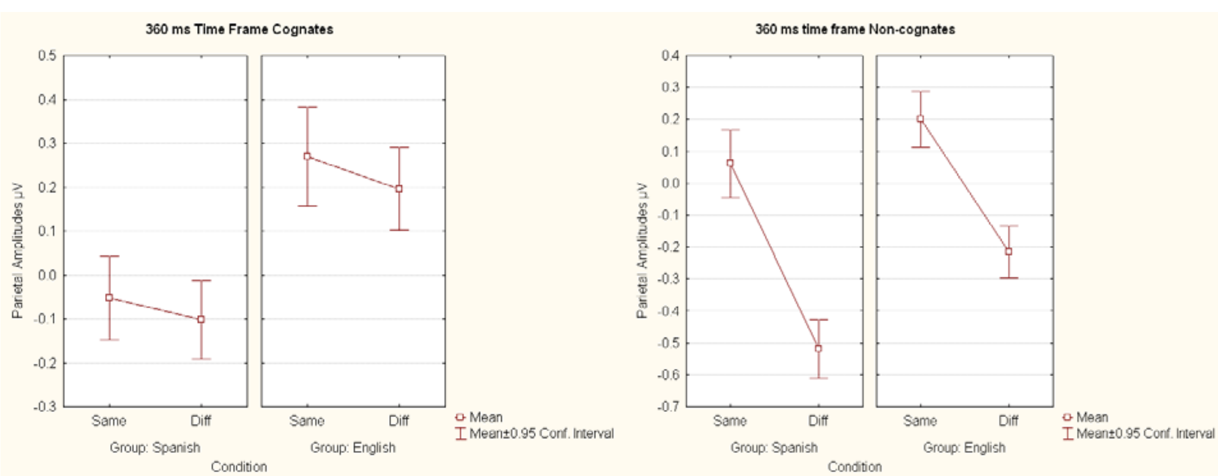


Figure 5a & b. (a) parietal electrode amplitudes in the 360 ms time frame for cognates. Note that monolingual participants are demonstrating more positivity overall. (b) parietal electrode amplitudes in the 360 ms time frame to non-cognates, note similar responses from both language groups.

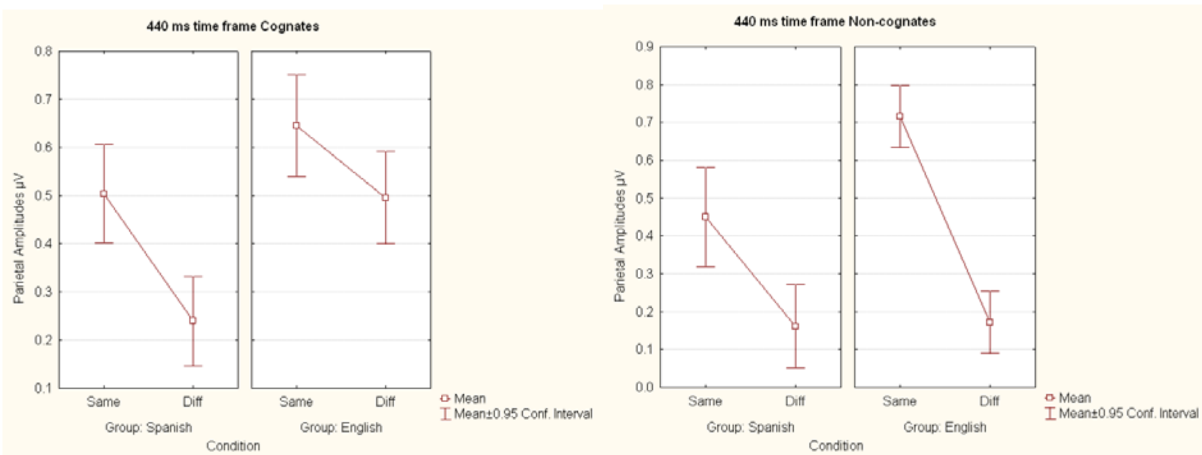


Figure 5c & d. (a) parietal electrode amplitudes in the 440 ms time frame for cognates where there was not a significant interaction of Group x Condition. (b) parietal electrode amplitudes in the 440 ms time frame to non-cognates where Group x Condition was significant.

The times frames spanning from 360 ms to 519 ms were analyzed for the presence of an N400 component to evaluate the effect of the phonological priming from the first word presentation. These time frames were not combined due to weak correlations (r<0.5). A main effect of Condition was observed in the 440 ms time but not the 360 ms time (see Table 13 for statistics). All listeners showed more negative amplitudes to different compared to the same trials. A significant interaction of Group x Type x Condition was demonstrated only in the 440ms time frame. Inspection of this interaction in the data reveals a more negative response to non-cognate different trials (fig. 9). In the 360-439ms time frame, both groups demonstrated almost equal amplitude responses to same and different trials for cognates (see Fig. 5a). A step-down analysis was completed for the 440 ms time window removing the factor of Type and assessing cognate and non-cognate responses separately. Non-cognate trials revealed a significant effect of Condition ($p<0.001$) and a significant interaction of Group x Condition ($p<0.001$). Cognate words revealed a significant effect of Condition ($p<0.001$) but did not reveal a significant interaction of Group x Condition (see Fig. 5a). Figure 6 shows that bilinguals and monolinguals had similar responses to cognate words but differed in their responses to non-cognate words. There was also significant differences in variance across language groups for the non-cognate Different condition (F(1,27)=4.59, $p<0.01$) but not for the cognate Different trials (F(1,27)=1.4, $p=0.25$).

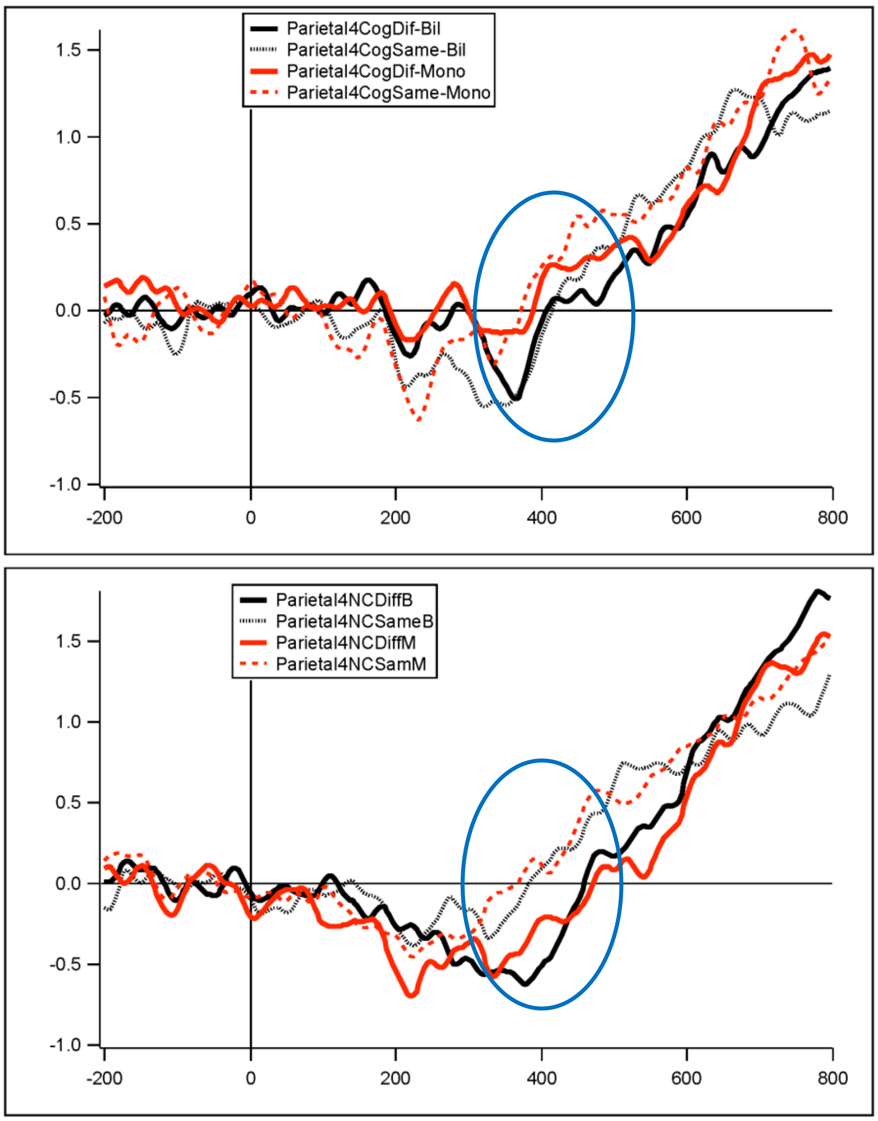


Figure 6: Parietal model showing Cognates above and Non-cognates below. Solid lines represent Different trials. Red lines indicate monolingual participants. Blue circle indicates the time frame of interest.

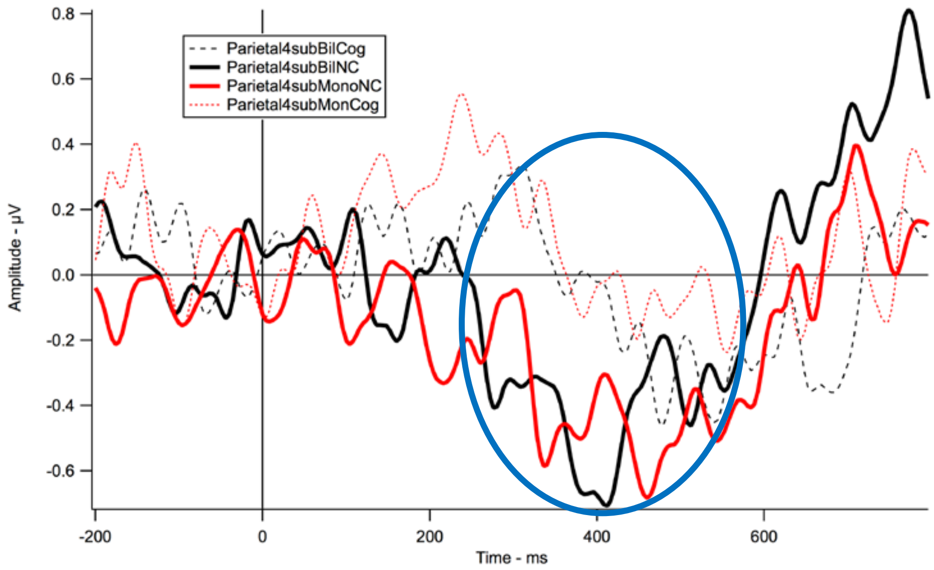


Figure 7: Parietal model showing monolingual (red lines) and bilingual participants (black lines) subtraction wave for cognates (dotted lines) and non-cognates (solid lines.) The blue circle indicates time frame of interest.

Inspection of subtraction waves indicate that both monolinguals and bilinguals show a negative deflection starting at approximately 220 ms and continuing on through 520 ms for non-cognate words, while for cognate words this negative deflection does not begin until 400 ms (Fig. 7). This pattern suggests that both groups were able to access the target lexical item from cognate mispronunciations. In contrast, non-cognate mispronunciations were not considered to be equivalent to the target forms. If the target word was not perceived as an exact repetition, then a lexical search will most likely take place and would be evidenced by an increased negativity in the ERP responses.

3eii. Frontal model

Due to a high correlation (r >0.8) between the 360 and 440 ms time frames, they were collapsed for statistical analysis to form a 160 ms window. Results can be seen in Table 14. These times frames revealed a main effect of Condition (*p<0.001*), and significant interactions of Group x Condition (*p<0.001*) and Group x Type x Condition (*p<0.01*). In the case of the bilingual participants, they presented with a generally more negative response than monolinguals to cognate words and a smaller difference between their same/different trial responses to non-cognate words. When bilinguals were presented with a change in a non-cognate word their response was generally smaller than found for monolinguals (see Fig. 8 a&b). Monolinguals demonstrated a greater frontal positivity evidenced by a more positive going subtraction wave for non-cognate trials (Fig. 9).

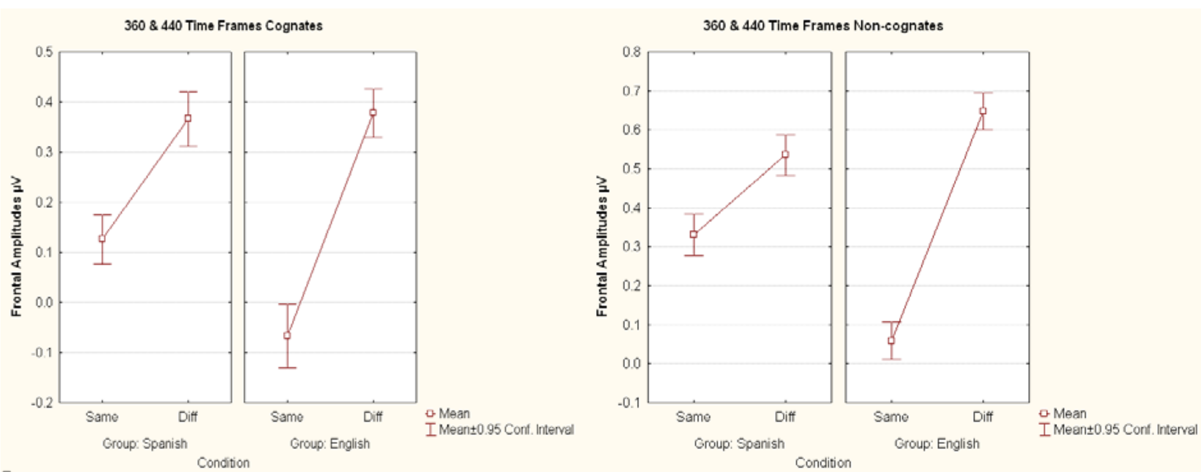


Figure 8a & b. (a) frontal model mean amplitudes in the 360 & 440 ms time frames for cognates. (b) frontal model mean amplitudes in the 360 & 440 ms time frames for non-cognates demonstrating a significantly smaller response to Different trials when compared to Same trials from the bilingual group.

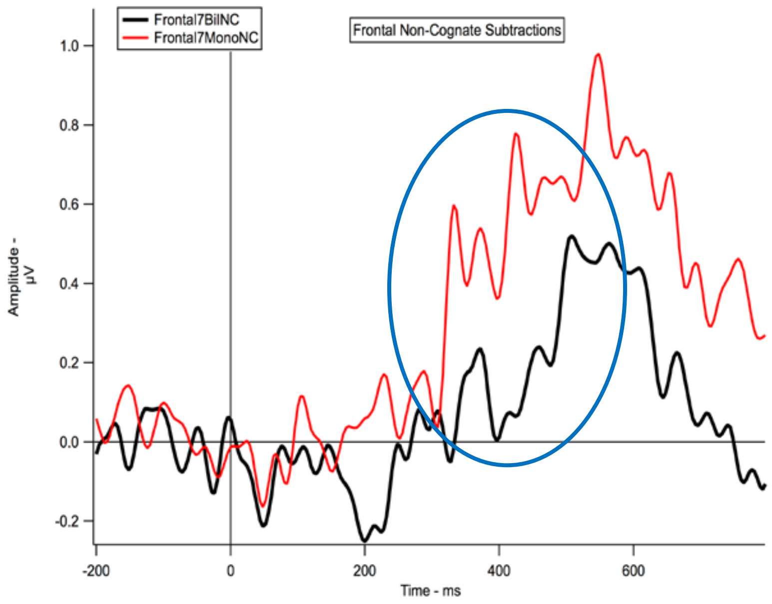


Figure 9. Subtraction waves for frontal electrodes to non-cognate words, note monolingual subtraction wave demonstrating greater positivity. The blue circle indicates the time frame of interest.

Table 14. Mixed model results from Frontal electrodes at the 360 & 440 ms time frames.

Frontal Electrodes 360 & 440 ms time frames	**Estimate**	**Std Error**	**t-value**	**Pr(>|t|)**
Group	-.01	.22	-.056	.95
Type	.269	.02	9.3	.000**
Condition	-.44	.02	-15.3	.0000**
Group x Type	-.09	.04	-2.4	.014*
Group x Condition	.2	.04	5.01	.0000**
Group x Type x Condition	.18	.06	3.08	.0021*

$*p<0.01$, $**p<0.001$

3f. Epochs including 520, 600, 680, and 760 ms

3fi. Parietal

Table 15. Mixed models results for Parietal electrodes at the 520 & 600 ms times frames as well as 680 & 760 ms time frames.

Parietal Electrodes	Estimate	Estimate	St error	St error	t-value	t-value	Pr(>|t|)	Pr(>|t|)
	520-600ms	680-760ms	520-600ms	680-760ms	520-600ms	680-760ms	520-600ms	680-760ms
Group	-.12	-.55	.38	.42	-.3	1.2	.63	.19
Type	-.05	.06	.03	.04	-1.3	1.4	.18	.15
Condition	.09	-.14	.03	.04	2.4	-3.4	.01	.0007*
Group x Type	.16	.12	.05	.06	2.9	1.9	.005	.04
Group x Cond	.19	.21	.05	.06	3.6	3.4	.0001*	.0006*
Group x Typ x Cond	-.45	-.39	.07	.08	-5.9	-4.4	.0001*	.0000*

*$p<0.001$

Later time frames were analyzed for the presence of the LPC component. The time frames of 520 ms and 600 ms were collapsed due to high correlations (r >0.8). The analysis revealed a significant 3-way interaction of Group x Type x Condition (see Table 15 for statistics). In this time frame, the bilinguals begin to show differential responses to cognate vs. non-cognate words while monolinguals are responding to them in the same manner (Fig.10). Bilinguals' differential response to non-cognate words is evidenced by a positive deflection that is more quickly rising and of greater amplitude than their response to cognate words.

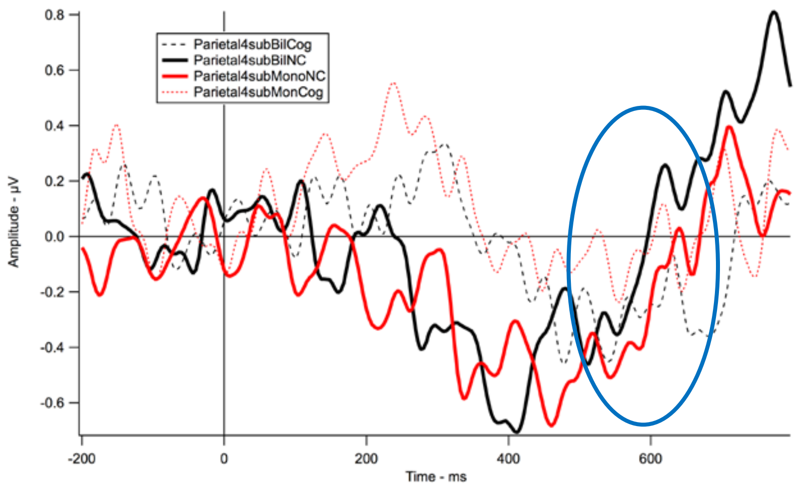
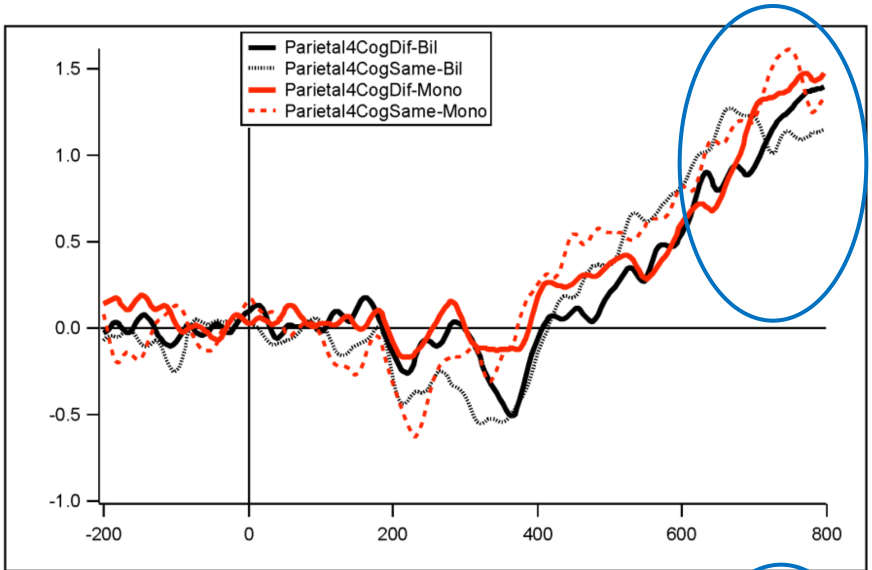


Figure 10. Parietal subtraction waves. Monolingual (red lines) and bilingual (black lines) responses for cognates (dotted lines) and non-cognates (solid lines). The blue circle indicates the time frame of interest.

The 680 and 760ms time frames were also highly correlated, and therefore, collapsed. The interactions of Group x Condition and Group x Condition x Type were significant (Table 15). For non-cognates, monolinguals do not demonstrate a large difference between the Same and Different trials, whereas bilinguals show a more positive response to different trials compared to same trials. In the case of cognates, a different pattern is observed. Monolinguals show a more positive response to different trials when compared to bilinguals (see Fig. 11).



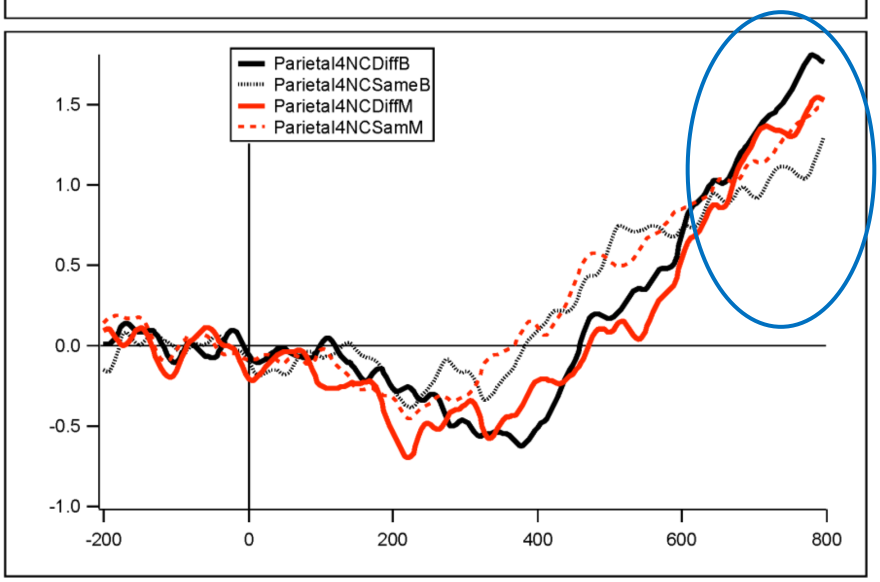


Figure 11. Parietal model electrodes for cognate (above) and non-cognate trials (below). The blue circles indicates time frames of interest. Note monolinguals are demonstrating greater positive responses to cognate Different trials than bilinguals.

3fii. Frontal

Table 16. Mixed model results from Frontal electrodes at the 520 & 600 ms times frames and the 680 & 760 ms time frames.

Frontal Electrodes	Estimate	Estimate	St error	St error	t-value	t-value	Pr(>|t|)	Pr(>|t|)
	520-600ms	680-760ms	520-600ms	680-760ms	520-600ms	680-760ms	520-600ms	680-760ms
Group	-.48	-.26	.27	.38	-1.7	-.69	.07	.48
Type	-.08	-.01	.02	.03	-2.7	-.43	.005	-.66
Condition	-.82	-.43	.02	.03	-27.6	-11.9	.000	.000
Group x Type	.16	-.04	.04	.05	4.02	-.7	.0001	.42
Group x Cond	.10	.0003	.04	.05	2.5	.007	.011	.99
Group x Typ x Cond	.24	.37	.05	.07	4.1	5.1	.000**	.000**

High correlations between the first and the second two time frames resulted in collapsing of these four times into two separate 160 ms windows for analysis. The first time frame (beginning at 520 ms and ending at 679 ms) revealed a significant interaction of Group x Type x Condition (Table 16). Analysis using only Group and Condition for both cognates and non-cognates revealed a significant interaction of Group x Condition ($p<0.01$). This interaction again is demonstrated by an attenuated positive response by bilinguals to Different trials to both word types and a more negative response to Same trials for cognates (Fig. 12). Bilingual responses to different trials for non-cognates are more positive than responses to different trials for cognates; however the difference between the Different and Same trials is greater for cognates (Fig. 13). It is also of note that this late positive response comes earlier for monolinguals (at approximately 350 ms) than for bilinguals (just after 400ms) when viewing the subtraction wave (Figs. 14 & 15).

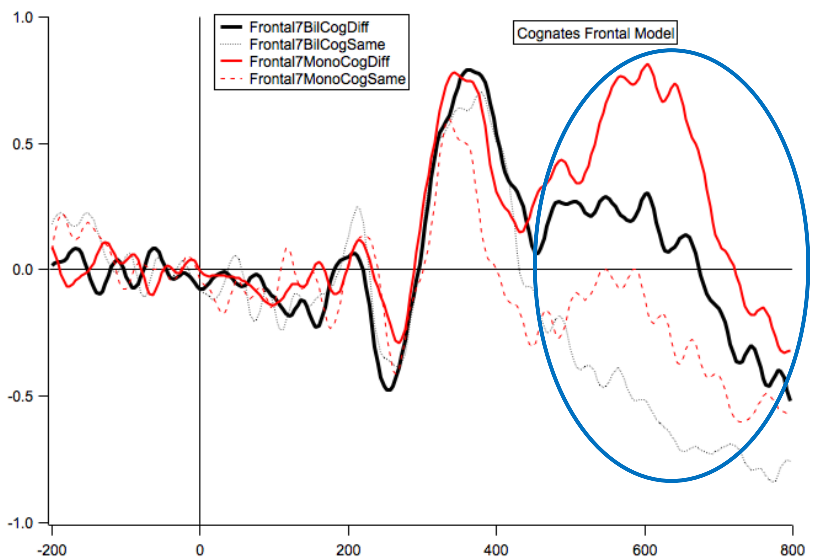


Figure 12: Monolinguals (red lines) and Bilinguals same and different trials for cognates only in frontal model. Different trials are represented by solid lines. The blue circle indicates the time frame of interest.

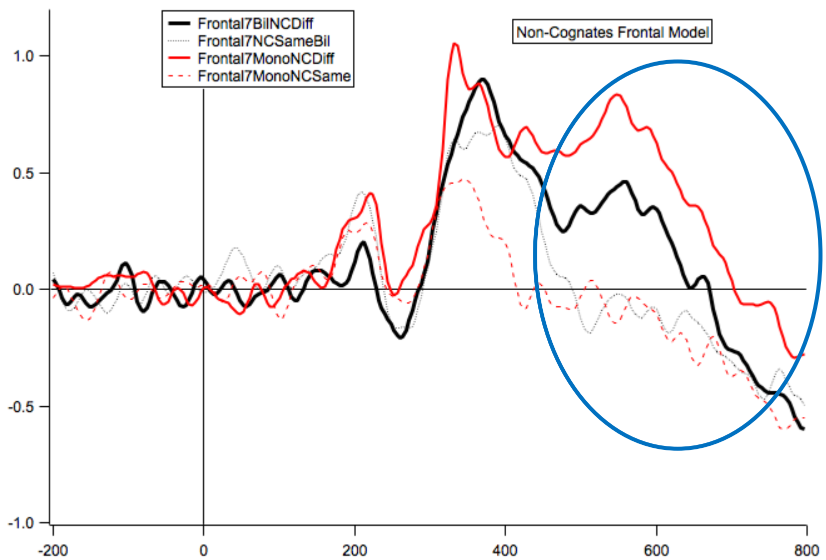


Figure 13 : Monolinguals (red lines) and Bilinguals same and different trials for non-cognates only in frontal model. Different trials are represented by solid lines. The blue circle indicates the time frame of interest.

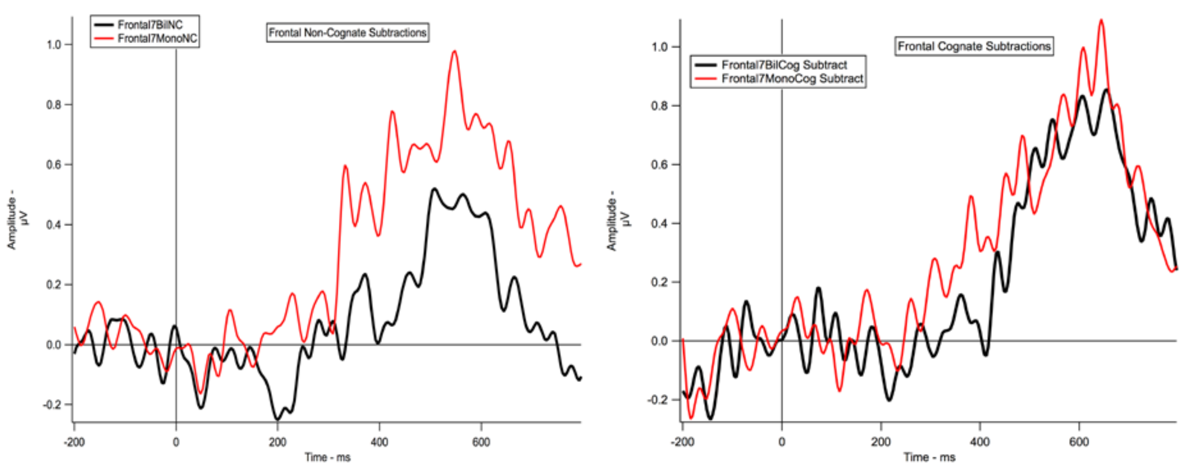


Figure 14 a & b: a) Frontal model Monolinguals and Bilinguals Non-cognates only. Subtraction waves are demonstrated with Monolinguals represented by the dotted line. b) Frontal model Monolinguals and Bilinguals cognates only. Subtraction waves are demonstrated with Monolinguals represented by the dotted line.

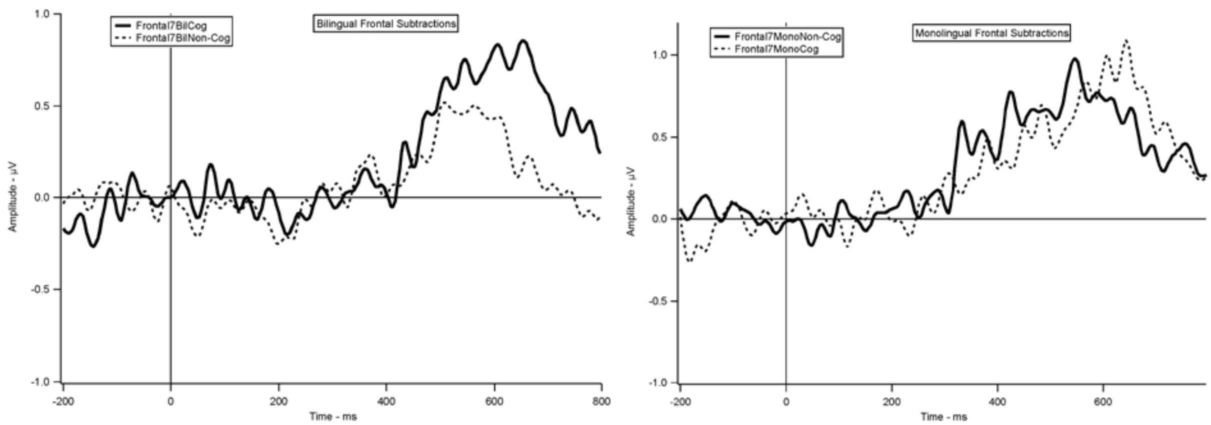


Figure 15 a & b. (a) Subtraction waves for bilingual participants at frontal sites. Solid line represents cognate trials. (b) Subtraction waves for monolingual participants at frontal sites. Solid lines represent cognate trails.

In the time frame including 680-800 ms, there was a main effect of Condition as evidenced by more positive going waves for different trials in both language groups (Table 15). There was also a significant interaction of Group x Type x Condition (t=5.16, $p<0.01$) evidenced by a larger response to different non-cognate trials for monolinguals compared to bilinguals. A step-down analysis was completed by removing the Type factor and analyzing cognate and non-cognate trials separately. Both cognates and non-cognates revealed a significant effect of Condition ($p<0.001$). Only non-cognate trials revealed a significant interaction of Group x Condition ($p<0.001$). Bilinguals in this time frame are demonstrating minimal differences in their responses to Same and Different trials for the non-cognate words (Fig. 16). This can also be seen in the waveforms by a less positive response produced by bilingual participants in comparison to monolingual participants (Fig. 13). In fact, bilingual responses to different trials were similar to both bilingual and monolingual responses to same trials.

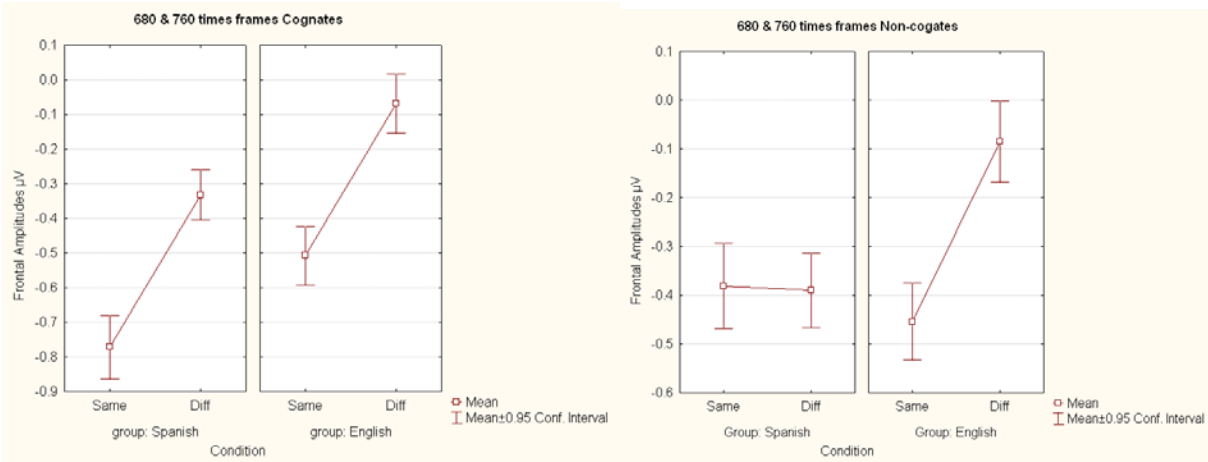


Figure 16a & b. (a) frontal electrode mean amplitudes in the 680 & 760 ms time frames to cognate words, monolingual and bilingual responses are similar as evidenced by lack of a Group x Condition interaction. (b) frontal electrode mean amplitudes in the 680 & 760 ms time frames to non-cognate words, bilingual participants demonstrating little to no awareness of vowel changes as indicated by a significant interaction of Group x Condition.

Visual inspection of the data reveals that both language groups demonstrated similar responses to the Same trials for non-cognates, with bilinguals having an attenuated response to Different trials when compared to monolinguals. This positive response begins to turn negative at approximately 760 ms. Overall, the two language groups demonstrate similar patterns of response to cognate words, but a differential response to non-cognate words at frontal sites (Fig. 16a&b). There appears to be somewhat more variability in the Spanish language group, particularly for non-cognate different trials (Fig. 17). These plots are shown using subtraction waves (same trials subtracted from different trials), which demonstrate a more negative subtraction wave for bilinguals in the three latest times (fig. 14a & 15a). Subtraction waves for bilingual participants reveal a more positive response to cognate trials (fig. 15a). It should be noted that variance for subtraction waves was not statistically significant for cognates ($F(1,27)=1.69$, $p=0.17$) or non-cognates ($F(1,27)=.41$, $p=0.94$), but variances of the Different amplitudes for non-cognates was significant (F(1,27)=3.93, $p<0.01$) while the variance of cognate Different trials was only approaching significance (F(1,27)=2.4, *p=0.058*).

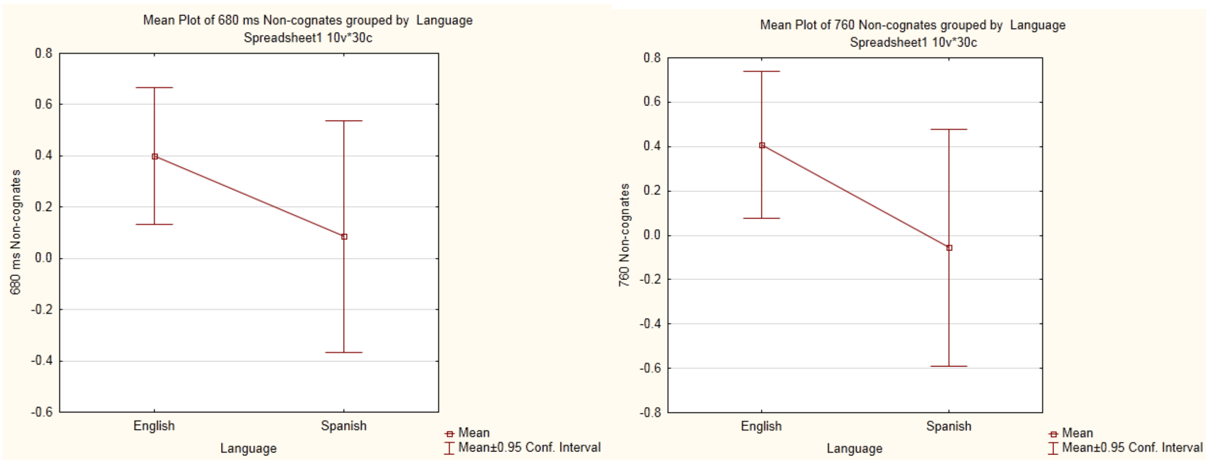


Figure 17: Mean amplitude plot graphs of the 680 & 760 ms time frame for non-cognate subtraction waves, demonstrating a more negative mean amplitude for bilingual participants as well as greater overall variability in the bilingual group.

3g. Directionality

It was hypothesized that the direction of the presentation of the stimuli would have an effect on the size of the ERP response to Different trials. Specifically, the response to a Different pair where the accented version of the word was presented first was expected to demonstrate a less robust response than for the opposite direction. Analyses were completed in the 360 and 440 ms time frames in the parietal region and in later frames for the frontal regions to determine whether there were differences related to directionality.

3gi. Parietal

Further analysis was completed in 360 and 440 time frames breaking down same and different trials into NSS (non-cognate standard-standard), NAS (non-cognate accented-standard), NAA (non-cognate accented-accented), and NSA (non-cognate standard-accented). A similar division was made for cognate words. Results of mixed-model regressions for 440 ms revealed a significant interaction of Group x Condition for all types of trials ($p<0.01$). This effect is demonstrated with the bilingual response to same and different trials for the NSS-NAS pair showing minimal difference, while monolinguals are demonstrating a large response to this vowel change when the accented word is presented first (fig. 18a). For the 360 ms time frame a significant interaction of Group x Condition was present for the NSS compared to NAS types ($t=-5.8$, $p<0.001$) while the NSA types only approached significance ($t=-1.9$, $p=0.056$) and waveforms reveal similar responses sizes across groups (see arrows in Fig. 18b). When NAS and NSA were examined separately, there was a significant interaction of Group x Condition ($t=-1.9$, $p<0.05$). Visual inspection of these categories separately reveals that bilinguals show a negative deflection later than monolinguals (at approximately 200 ms) and becoming positive earlier (at approximately 440 ms) while for monolinguals the waveform remains negative until 600 ms for the NAS trials. Bilinguals demonstrate a smaller difference between their response to same and different trials when the different trials are of the NAS type when compared to monolinguals (Fig. 18a). This may be due to their accepting the accented version as an appropriate variant of the word. When this same analysis was completed with different types of cognate trials, a significant interaction of Group x Type was also observed in both time frames ($p<0.001$).

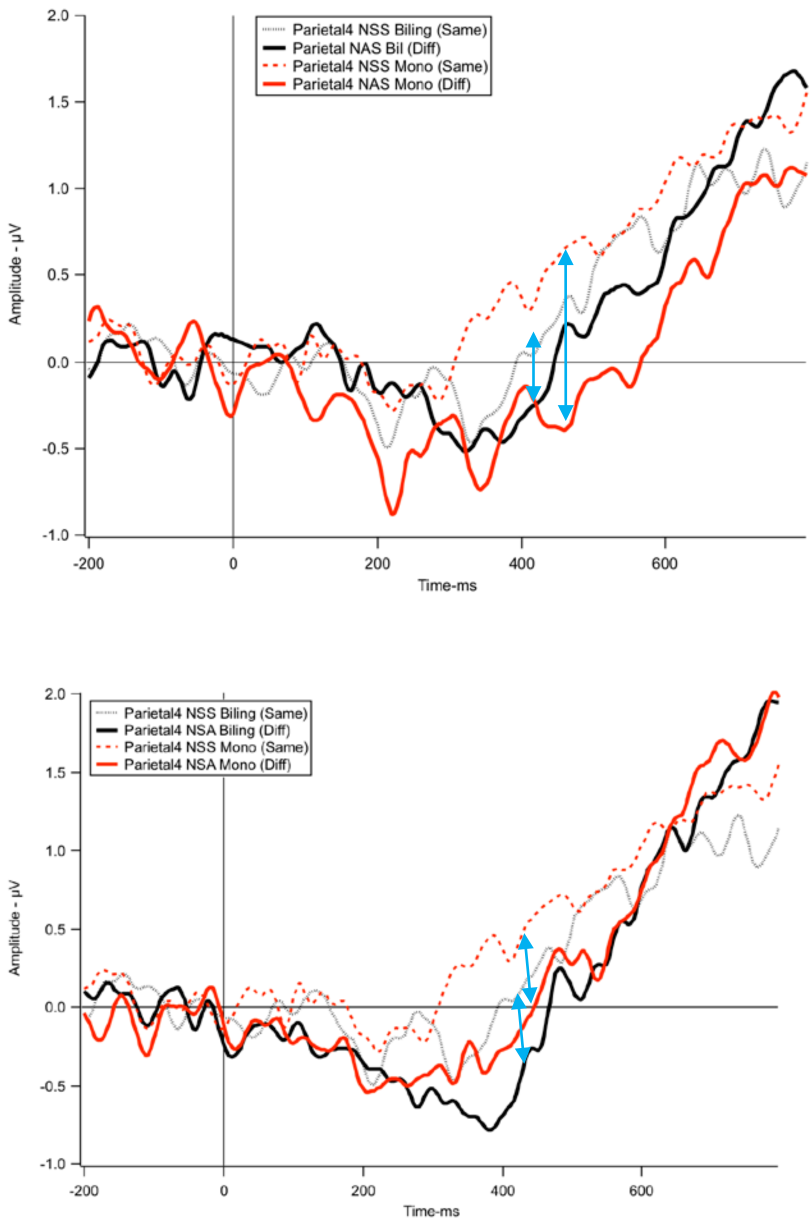


Figure 18 a& b: a) Non-cognates Same (standard-standard) with Different (Accented-Standard) for monolinguals and bilinguals. Thicker solid lines are different trials, with black representing bilinguals. b) Non-cognates Same (standard-standard) with Different (Standard-Accented) for monolinguals and bilinguals. Thicker solid lines are different trials, with black representing bilinguals. Blue arrows indicate time frames of interest.

3gii. Frontal

Comparison of NSA with NAS (the two types of Different trials) for the 520 & 600 ms time frames revealed a significant interaction of Group x Condition (t=5.8, $p<0.001$). Comparison of NAS with NSS did not demonstrate a significant interaction of Group x Condition, while NSA with NSS did reveal a significant interaction of Group x Condition (t=2.1, $p<0.05$). In contrast, there was not a significant interaction of Group x Condition for CSA/CAS or CAS/CSS.

An analysis was also completed in the 680 and 760 ms time frames. All trials types revealed a main effect of Condition except for Non-cognates NSA/NSS. All conditions also revealed a significant interaction of Group x Condition except Cognates CAS/CSA ($p=0.22$) and CAS/CSS, which was approaching significance at $p=0.053 (t=-1.9)$. These findings agree with the previous statistical results as well as visual inspection of the data in that cognate trials reveal less difference between the language groups than the non-cognate trials. Within the non-cognate trials, the interaction of Group x Condition is demonstrated by an average increase in amplitude of 0.36 µV for the monolingual response to NAS trials compared to the bilingual response to NAS trials (Fig. 18a). This pattern is similar to that demonstrated at parietal sites where the difference between same and different responses is greater in the monolingual group for NAS trials when compared to NSA trials (Fig. 18a & b). Monolingual and bilingual responses to the NSA trials were comparable. Bilinguals have more difficulty perceiving a change in a vowel sound when the target word is primed by a word with a vowel that is more Spanish-like (accented).

3h. Correlations between ERP and behavioral measure

Correlations were undertaken using the time frames of interest for the N400 component (parietal electrodes 360 & 440 ms), the LPC component (parietal 680 & 760 ms), as well as time frames of interest for the late frontal positivity (frontal 680 & 760 ms) to examine whether ERP responses were related to language proficiency as measured by language testing. The tests of vocabulary, grammar, language background questionnaire ‘Use’ quotient, and the participants’ self-rating of English proficiency were used in this analysis. The only measure of proficiency that was correlated with an ERP component was between participant self-rating of overall proficiency in English and the LPC component for the 680 ms interval (r = 0.57) (Fig. 19).

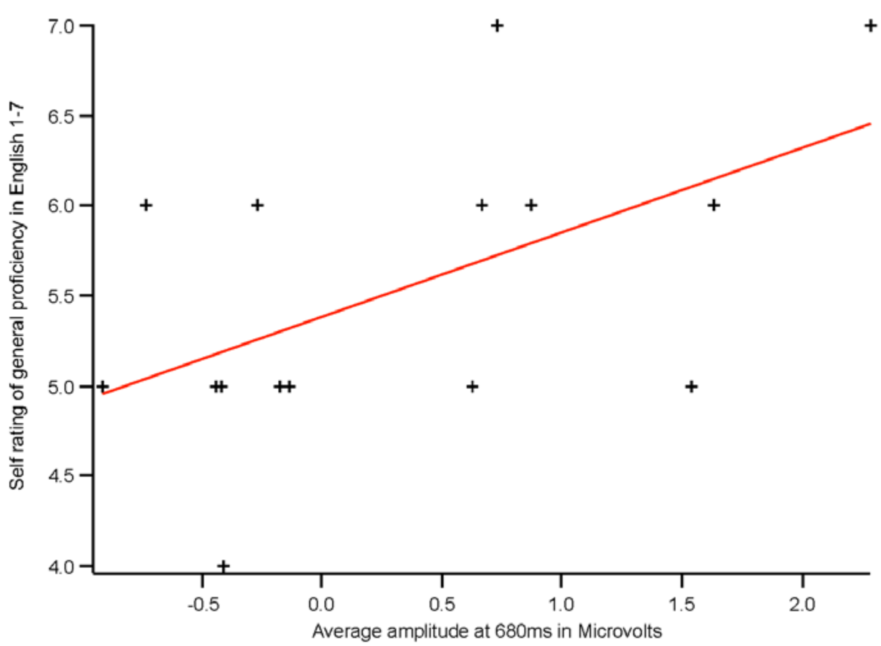


Figure 19: Correlation of self-ratings vs. average amplitude of the parietal response (LPC) at the 680 ms time frame. A higher self-rating for proficiency in English was correlated with a more robust LPC response. X=amplitude, Y=self-rating. Pr=.57, $p<0.05$.

Chapter 4: Discussion

4a. General Findings

The goal of this study was to determine whether the phonological/semantic relationship (cognate status) between lexical words of a bilingual's two languages influences speech discrimination. The main findings revealed that cognate status did influence processing of these forms for the bilinguals, but not in the expected way for the N400. Both monolingual and bilingual groups showed a larger N400 to target words in the non-cognate than the cognate category. In contrast, the monolinguals showed an equally large late frontal positivity (P400) for both cognates and non-cognates. Bilingual participants showed a larger frontal positivity in the later time intervals to non-cognate compared to cognate target words starting at approximately 400 ms. Bilinguals also demonstrated a differential response to the different word pairs depending on which direction the standard and accented version were presented. The bilinguals showed a similar response to monolinguals when the standard version of the word was presented first, but demonstrated minimal recognition of the vowel change when the accented version of the word was in the prime position. This finding was true for non-cognate pairs but not cognate pairs. In addition, monolinguals showed generally better discrimination as measured by behavioral and ERP responses. Monolinguals demonstrated better accuracy in their same/different behavioral judgments. Below we explain the pattern of results more fully in relation to our hypothesis.

4b. Cognate versus non-cognate words

We hypothesized that monolingual participants would have no difficulty discriminating Same and Different pairs and would demonstrate an N400 component in response to the phonological mismatch in the Different pairs. We also predicted that cognate words might provide a perceptual enhancement for bilinguals, which could lead to better discrimination of the standard and accented forms. This would be seen as a larger N400 for bilingual participants. Alternatively, it was possible that the non-cognate words would demonstrate a larger N400 if the cognate words were processed using L1 perceptual routines. Our findings did not straightforwardly address this prediction because both monolinguals and bilinguals showed a larger N400 to non-cognates than cognate words. This finding suggested that some other factor may be operating.

The N400 is thought to index difficulty in retrieving a specific item from our stored semantic memories (Duncan, et al., 2009). In the case of the current design, the Same condition was expected to lead to full priming (identity priming) of the target, and thus, little or no negativity would be observed in the N400 time frame. The Different condition would show some priming from the similar target, however, to a lesser extent than for identity priming. Thus, relatively greater negativity for the Different than Same condition would indicate that the prime word did not fully facilitate lexical access to the target and indicates that the two forms were not treated equally in access to the lexical representation.

Overall, monolinguals did not demonstrate any difficulty behaviorally discriminating Same from Different pairs, however, they did demonstrate cognate versus non-cognate difference. It is unclear why the N400 difference for cognates compared to non-cognates was seen in the English speakers. In addition, the cognate words appeared to be primed by the accented or standard versions of the word for both monolingual and bilingual groups. Past studies have demonstrated that increased phonological dissimilarity between the prime and target will result in less facilitation or possibly inhibition of access to the target (Dijkstra, 1999). This suggests that bilinguals may perceive these accented versions of the cognate words as homophones (or allophonic variations) instead of mispronunciations and this results in little difference in the N400 latency range. However, the finding from the monolinguals weakens the confidence in this explanation. It is possible that both groups perceived acoustic and timing differences present in the words that were not related to cognate status (although acoustic measurements of the stimuli do not show a difference, see below). Alternatively, it may be that monolinguals from the New York City area have some awareness of Spanish cognates because Spanish can be heard in many contexts (e.g., on subways and buses). It may be that monolinguals learn to accept these variant Spanish pronunciations for their English counterpart, and for this reason access the lexical entry from these mispronunciations.

In addition, after separating the words with regards to directionality (i.e., whether the accented word was presented as the prime or the target) language-group differences were seen for the N400 in relation to cognate and non-cognate status. Below we suggest explanations for this finding in the context of directionality of presentation (i.e., which form served as prime versus target).

4c. Direction of stimulus presentation

We had predicted that there would be directionality effects for bilinguals based on whether an accented or standard version of the word was used as the prime in the Different trials. Specifically, the standard to accented direction for non-cognates (NSA trials) would have a later and smaller response, as this would be equivalent to L2→ L1 translation. It was also predicted that cognate trials would not demonstrate a directionality effect, at least for bilinguals. The initial prediction regarding cognate trials was confirmed in that cognate words exhibited more similar responses across the trial types than non-cognate words. However, the prediction that non-cognate standard to accented direction would demonstrate a smaller response than the opposite direction (NAS trials) was not confirmed. In fact, the opposite pattern was observed, with the non-cognate standard-accented order producing a response pattern in bilinguals similar to that of the monolingual participants and non-cognate accented-standard order demonstrating less difference in both the parietal N400 and frontal models for bilinguals when compared to monolingual participants. This pattern suggests that the accented prime form led to access to the lexical representation and strongly facilitated (primed) access to the target form. In contrast, the standard pronunciation of the non-cognates did not strongly prime (or less strongly prime) the accented form. In the case of bilinguals, the accented version of the word may be more likely to prime the standard version of the word as they may have variants of L2 words stored in their vocabulary due to differences in L2 phonological perception. These differences in phonological perception may cause the two versions of the words to be represented as homophone pairs (or allophonic variants).

4d. Cognates and their effect on lexical access

Previous priming studies have demonstrated co-activation of L1 equivalents when L2 words with cognates are presented (Sanchez-Casas, et. al, 1992). An L2 word with similarities in orthography and phonology to an L1 word facilitates lexical access of both word forms. Findings from the current study suggest that lack of an L1 phonological equivalent allowed for more accurate discrimination of same versus different pairs. As discussed above, both bilinguals and monolinguals demonstrated a larger and earlier N400 component to different pairs for non-cognates, than for cognates. It is possible that in the current study the "N400" component observed in the parietal region reflects differences in the acoustic-phonetic properties of the two word categories, rather than cognate status. As mentioned above, however, examination of acoustic correlates and the frequency of the words in the two categories did not reveal any obvious phonetic differences or differences in statistical properties. Above, we suggested that it was possible that both bilinguals and monolinguals accepted the accented cognate forms as variants of the target word. Interestingly, an ERP study of highly-proficient Catalan-Spanish bilinguals suggested that Catalan-dominant bilinguals had learned to tolerate mispronunciations of the Catalan vowel [E] as [e] (phoneme category in both Spanish and Catalan), and performed lexical access (seen as no increase in N400 to mispronunciations) (Sebastian-Galles et al., 2006). However, the error-related negativity indicated that the Catalan-dominant listeners recognized the error, whereas Spanish-dominant listeners did not. In our study the monolingual English participants may have had sufficient experience with Spanish-accented English to accept many of the cognate words as variants of the target. This would support the assumption that production of cognates word forms are associated with a higher level of accentedness. A future study, using a lexical decision task, could clarify whether monolinguals would show faster access to the lexical entries for cognate than non-cognate mispronunciations, and to what extent this is influenced by the number of Spanish speakers in the community. This study could be completed in a highly bilingual community such as south Florida.

The LPC was predicted to show greater positivity in response to the second word in a different pair (Nagy & Rugg, 1989). The LPC has also been shown to represent differences in speech perception based on native language experience (Wagner, et. al, 2012). A study with a somewhat similar design to ours, which examined non-native speech perception, revealed that a greater phonological difference between the prime and target word resulted in a larger LPC (Dehaene-Lambertz, Dupoux, & Gout, 2000). In the current study, the LPC component was expected to be larger for changes within cognate words, because they are more familiar and more deeply embedded in the bilinguals' episodic memory. This familiarity could lead to improved perception. The LPC is sensitive to lexical items that are well programmed and practiced in an individual's vocabulary; therefore, it could be expected that words that access an L1 representation would result in greater LPC amplitude (Rugg & Curran, 2007). It is possible that bilinguals are being primed by both the standard and accented versions of the cognate words and therefore do not have to "work as hard" to retrieve the lexical entry when they hear the target word. In contrast, for the non-cognates, they may have to work harder to access a lexical entry thereby explaining the larger positivity to these words. It is also of note that the LPC has been known to show greater positivity to real words rather and nonsense words (Nagy & Rugg, 1989). For this study, it could be postulated that the accented non-cognate words could be perceived as nonsense words by the bilingual group, again suggesting a prediction of greater LPC amplitude to cognate words. The LPC has also been shown to be modulated by response selection (Verleger, Jaskowski, & Wascher, 2005). Given that the participants in the current study were asked to make a discrimination judgment, the LPC may reflect the difficulty in detecting a stimulus difference.   It is important to keep in mind that participants made decisions about the Same and Different pairs. In the case that the participant incorrectly labeled a Different trial as a Same trial, this would result in a smaller amplitude LPC to the specific trial. However, for the purposes of this dissertation, incorrect and correct trials were averaged together for reported ERP responses.

The frontal component also demonstrated differences across cognates and non-cognate trials for the bilinguals. In the current study, there was evidence in the later time frames to indicate that the familiarity of a word's phonological and semantic relationship (i.e., whether or not it had a cognate) enhanced discrimination of vowels within that word. The frontal component provided evidence that the bilingual Spanish-English speakers process the cognate words at this level in a more similar fashion to the monolinguals. Both language groups showed significant differences between same and different trials to these cognate word pairs peaking at approximately 600 ms post word onset. The ERP difference between Same and Different trials for non-cognates was significantly diminished in the bilingual group. It appears that lexical familiarity enhances speech perception and general phonological discrimination. Cognates are assisting bilinguals not only at to the level of lexical access, but also at the level of phoneme perception within a word. The fairly late time suggests that this frontal component may be an index of conscious discrimination of speech sounds.

Theories of bilingual lexical access propose that words in both languages are accessed in a parallel manner (De Bot, 1992; Costa, Miozzo & Caramazza, 1999). Lexical selection in bilinguals does not appear to be language specific and research with bilinguals demonstrates that access to cognate equivalents appear to be at a lower threshold for activation for lexical access

(Colome, 2001 & Costa, et. al, 1999). This suggests that a cognate word is more easily accessed in both L1 and L2. According to Dell's cascading view of lexical access, spreading activation across lexical entries with similar phonological properties will occur. In this case, all lexical entries in both languages sharing phonological properties will be activated and in the case of cognates, could cause confusion for bilinguals in the selection process because they might select the incorrect language form. In contrast, Levelt's theory suggests that once the correct node has been selected, the phonological segments of only the chosen node are retrieved and irrelevant phonological information will be discarded. Dell's theory would suggest that bilinguals were activating the phonological properties of all competing items in both languages during the lexical selection process, and this would result in a greater challenge for accessing the correct cognate word form. For late-bilinguals in particular, who would not be expected to have formed native-like phoneme categories in their L2, activation of all entries until the instance of the lexical selection process may cause interference between cross-language word forms that are similar. If cognate words and their translation equivalents led to activation of phonologically similar competitors in both languages during the lexical selection process, then we would expect less accurate phonological discrimination or a longer time-course of access for these words. The results of the current study are partially consistent with Dell's claim. Standard and accented cognate forms seem to equally allow for lexical access with respect to the N400 measure. However, the frontal positive component finding does not fit with the model because the cognate words showed larger discriminative responses. Perhaps Dell's model explains the early operation of the system, but Levelt's model is correct in indicating that once the lexical item is selected, incorrect phonological information can be inhibited. The ERPs suggest that this happens fairly late in the process. In this case, only the phonological properties of the chosen lexical item will be present once it is retrieved. For bilinguals it is probable that they are retrieving the correct lexical item with incorrect phonological properties based on their L1 phoneme categories and for the non-cognates, they are less likely to recognize that the phonological properties are incorrect. It appears that both lexical access theories are necessary to account for the pattern of findings in the current study.

4e. L2 proficiency

All participants in this study demonstrated conversational proficiency in their L2. Responses to the same/different response task indicated that both language groups were able to discriminate the changes in the vowel sounds, but monolinguals performed significantly better than bilinguals based on their accuracy scores. Participants in the bilingual group who demonstrated the most difficulty with this task did not show poor performance on other tests of language proficiency. It is possible that the language tests used in this study were not sensitive enough to identify the less proficient bilinguals. Although this researcher anecdotally observed higher levels of English proficiency in participants with social exposure to English (e.g., having an English-speaking spouse), the proficiency tests used during this study were not sensitive to these advantages and significant correlations between spousal language and behavioral scores, ERP amplitudes, or other proficiency measures were not observed ($r<0.5$). Tests of proficiency assessed vocabulary awareness and grammar judgments, but no tests of phonological discrimination or identification were completed, except for the behavioral discrimination task during the ERP session. It is possible that some of the bilingual participants have adequate English vocabularies and experience to allow them conversational capacities, but continue to have less accurate phonological perception in their second language than monolinguals. The ERP amplitudes of the LPC and frontal positivity were not correlated with age of acquisition

(AOA) or length of residence (LOR). However, all of these participants were selected to be of fairly high proficiency. Past studies have shown that AOA strongly correlates with general proficiency (e.g., Oyama, 1976 & Flege, 1995). After having attained a high level of language proficiency, it seems that performance in L2 speech perception has to be accounted for by other factors. The only significant correlation was between self-ratings of proficiency and the LPC component, which accounted for about 32% of the variance. Thus, it seems that participants' self-ratings included some awareness of speech perception abilities. One future direction of investigation would be to examine the bilinguals' English phonological production accuracy to determine whether it contributes to L2 speech perception accuracy.

4f. L2 Vowel Perception

Adult second language learners demonstrate L2 phonological perception based on Selective Perceptual Routines (Strange, 2006 & 2007). These routines are formed beginning with language exposure at birth and assist a language learner in parsing out the important information that allows us to identify language-specific phonemes in our native language. These routines assist us in L1 learning, but due to the relatively inflexible nature of adult L2 phonological learning, they can cause interference in the L2 learning process. The PAM-L2 model suggests that the phonemes that can be placed into two separate L1 phoneme categories will be discriminated in a native-like manner (Best & Tyler, 2007). In the case of the current study, past research indicates that the accented version of each of the three English target vowels will be assimilated by Spanish listeners into one phoneme category (e.g., [I] assimilated into /i/), rather than two categories expected for English listeners (Fox, Flege, & Munro, 1995 & MacDonald, 1989). Perceptual assimilation of two English phonemes into one category for a Spanish listener will cause difficulties perceiving differences in phonologically similar words.

Confusion of words that differ in the L2 by one phoneme, but that are assimilated into one phoneme category in the L1 (for L1 monolinguals) has been demonstrated even in early bilingual populations (Sebastian-Galles, et. al, 2006.)

This study hoped to gain information regarding vowel perception in a second language when it is learned as an adult. Unlike many previous studies, this study used natural speech and real words to assess the participants' abilities regarding the perception of correct versus mispronounced vowels within an L2 word. Previous studies have shown that even experienced L2 learners demonstrate differences in their L2 vowel perception (Flege, et. al, 1997). Furthermore, this Flege study demonstrated that experience with a language could improve phonological perception whereas other studies have demonstrated that LOR does not necessarily lead to a significant improvement in L2 phonological perception (Munro, 1993). Large differences in length of residence in the current study (a range of three months to 24 years) did not correlate with differences in ERP responses, possibly due to similar levels of conversational proficiency. It is also important to note that all but two bilingual participants (who obtained associates degrees) received at least a bachelor's degree, making them a highly educated group of immigrants. Their level of education may also place this group at an advantage in their speech perception abilities.

The changes or 'accents' placed on the stressed vowels in the current study were meant to simulate what the bilinguals may perceive when listening to native English speakers using these words. Although a slight change in one sound of a word may not lead to inaccurate perception of the word, in many instances this one change can affect the meaning of the word and lead to confusion on the part of the L2 listener. In the current study, results from the frontal model indicated that accurate speech perception is modulated by cognate status; thus, words that are more closely related to words in the L1 will be processed more accurately. The current study also presented words where meaning changes based on this vowel change (e.g., ‘battle’ was changed to a production close to ‘bottle’). Due to the small number of these specific word types in the current study it was not possible to construct separate ERP averages to gain an accurate picture of how these semantic changes impacted speech perception. However, it will be possible to examine accuracy and reaction time for the behavioral responses to these word pair types in a future analysis.

Bilingual participants in the current study demonstrated behavioral results that indicate most of them have begun to form new vowel categories. However, the demands on the current task were fairly low (discrimination of word pairs in a quiet environment). Even so, bilinguals were significantly worse at identifying ‘different’ pairs than they were at identifying ‘same’ pairs. It is also possible that some of the participants are judging the changes made to the vowels as either good or bad exemplars as they were only asked whether the words were pronounced the same or differently and not whether they were pronounced ‘accurately.’ It will be important in future research to determine which of the two pronunciations of the words would be considered accurate or inaccurate by the bilingual population.

4g. Results as they relate to past ERP research

Based on past research, the anticipated language-based differences were expected to be reflected in N400 and LPC modulation. This N400 component can serve as an index that a semantic and/or phonological mismatch has been detected (Praamstra, et al., 1994; Holcomb & Neville, 1990). In a previous study, bilinguals showed a diminished N400 response to vowel changes using vowel contrasts that are present only in their second language (Sebastian-Galles, et. al, 2006). In the current study the N400 component did not clearly indicate language specific effects. It may be that both the standard and accented forms led to access of the target form suggesting that lexical access is fairly robust to distortions of the signal.

Although the negative parietal-based component (which we are calling the N400) in this study was not found to be language specific, it did reflect lexical access. Notably, almost all Same trials included exact repetitions of the words and therefore full priming. Thus, N400 should be minimal to these trials. As discussed above, within this N400 time frame, language-based directionality effects were observed. Bilinguals demonstrated a less robust response to the vowel change when presented with an accented version of the word as the prime and a standard production of the word as the target. It appears that presentation of a more L1-like production of the word activates L1 phonological representations, making it more difficult for bilinguals to notice the vowel change. This difference is noted only in non-cognate trials, whereas cognate words do not demonstrate this difference. Words that are not present in the L1 vocabulary are more vulnerable to L1 perceptual routines based on native-language vowel categories. This finding is in agreement with the N250 component found in Schoonbaert's 2011 experiment, although it should be noted that this study presented words as visual and not auditory stimuli.

Their study revealed a robust priming effect from L2 to L1, but a less pronounced effect from L1 to L2.

This study also showed a frontal positive component that was sensitive to stimulus difference. Unlike the parietal N400 model, this frontal model demonstrated clear distinctions between the language groups in regards to their differential responses to cognates and non-cognates. This differential response was found in the later time frames and was evidenced by a diminished difference to Same and Different non-cognate trials from the bilingual group. When comparing the bilinguals to the monolingual participants, the bilingual response started later for both cognates and non-cognates and the response to non-cognates was significantly reduced. Thus, cognates do in fact provide enhanced phonological discrimination, which may allow for better perception. This component may be the same as the P400 component found when Polish and English listeners were presented with words that contained an initial consonant cluster that is present in Polish but not in English (Wagner, et. al, 2012). The Polish listeners in this study demonstrated an earlier response to the Polish 3-syllable nonsense words when compared to the English-speaking control group, but both groups showed a larger P400 to different pairs. This component represents higher-level conscious processing of the vowel change and contains both acoustic and linguistic components (Wagner, et. al, 2012). When this vowel change occurs within a more familiar lexical item, the brain detects this response more robustly, with the greater difference between the two words causing a greater positive response. The current study revealed a larger and earlier response to cognate than non-cognate words by the bilingual participants as the brain worked to access the correct lexical item after a mispronunciation was presented.

4h. Broader Impact

Research on adult bilingual language acquisition has demonstrated that even highly proficient late-bilinguals still demonstrate difficulties in phonological perception and production in their second language. It is therefore important for us to understand exactly what speech sounds and contexts pose the greatest challenges for these bilinguals. Comprehensive understanding of the backgrounds and language habits of bilinguals that demonstrate greater abilities in the area of speech production and perception in their L2 will prove imperative in assisting those individuals who demonstrate a greater difficulty to learn new speech sound categories in their L2.

All individuals tested in this study had daily exposure to English as well as a professional (job) or social (spouse) desire to become proficient in their L2. Given that phonology is the most challenging aspect of language acquisition in the adult population, it is important that techniques to assist in improved L2 phonological acquisition continue to be investigated. All too often, adult L2 language classes rely on vocabulary and grammar lessons and neglect the importance of phonological perception and production and the role it plays in the efficiency of L2 communication exchanges. L2 learners may also be relying heavily on cognate words to communicate and understand, especially with languages such as English and Spanish where translation equivalents are so prevalent.

Language testing using only vocabulary and grammar measures did not prove useful in assessing discernible differences in the phonological proficiency levels of the participants in this study. Participants that performed poorly on one language test did not necessarily perform poorly on others and no one participant demonstrated a clear limitation in their English vocabulary or grammar skills. Results from the ERP data do, however, indicate differences in speech perception abilities among these participants in relation to their response to Different trials compared to the monolingual participants. There is evidence that bilingual participants may have been aware of their speech perception abilities due to the correlation between the LPCV amplitude and self-rating of English proficiency. These results further demonstrate the need for a greater emphasis being placed on phonological awareness in the L2 classroom environment.

Among the educated individuals who choose to move to the United States and pursue careers in this country it is of great importance that their speech be understood by their future employers and colleagues and that they do not have significant difficulty understanding the speech of the individuals that they interact with in the professional environment. Language study that emphasizes phonological perception and production as well as places extra emphasis on words that do not share an L1 equivalent should prove worthwhile to this population.

4i. Future directions

The current study extended our awareness in regards to phonological perception in the L2 and how it is impacted by the lexical status of a word. Results indicated that when bilinguals hear words that are not cognates they have a more difficult time perceiving accurate and non-accurate productions of the words. This decrease in phonological perception accuracy could lead to errors and misunderstandings in communication exchanges.

One limitation to the current study was that the bilingual group of participants was a homogenous group in regards to their educational level and their conversational proficiency.

There was however a large variance in their LOR and AOA, although all participants began learning English at 14 years of age or older. Ideally a group that also included participants with less education and a lower level of conversational abilities could also be tested to assess whether these factors contributed to the outcome of the study.

This dissertation used only lax vowels in the stressed position. Spanish does not include any lax vowels and therefore these vowels may be more challenging to a second language learner. These bilinguals may have more accurate perception of tense vowels, which do not demonstrate as much variability in their realizations. Of the three lax vowels used in this study, one in particular (i.e., the /ɪ/ sound) has proven particularly difficult for Spanish speakers to discriminate from its tense counterpart, /i/ (Flege, 1997). Analysis of each vowel separately was not completed for the purposes of this dissertation, but may provide information in the future regarding accuracy differences across the three unstressed vowels.

Another factor that may further explain the ERP and behavioral patterns is the bilinguals' abilities in discriminating these vowels in isolation. Adding a discrimination and identification task using not only the three vowels utilized in this study, but also other English vowels could prove useful in predicting ERP outcomes and attaining a more comprehensive knowledge of proficiency levels in the L2 group. The words used in this group also varied in their frequency levels, which may have impacted the responses by both the bilinguals and the monolinguals. In future studies a more homogeneous list of words, all of higher word frequency and therefore greater familiarity should be used to ensure that both monolinguals and bilinguals are familiar with the presented words.

A future direction for this line of research would be to conduct a study using more frequently encountered words with half of the words being those where changing one sound changes the meaning of the word. It will be important to note if these types of errors occur less frequently, which would indicate that bilinguals recognize that the change in the vowel leads to a change in word meaning. It could also be useful to complete this experiment using an oddball paradigm to elicit the mismatch negativity ERP component in which cognate words and non-cognates words would be presented in trains with rare mispronunciations to examine the level of automaticity in discriminating the sound change. It is important that we understand the mechanisms behind successful speech perception in the second language to better assist the large population of non-native listeners immigrating to our country.

4j. Conclusions

This study examined how monolingual English speakers and late Spanish-English bilinguals processed changes in vowels as presented in word pairs. These word pairs consisted of both non-cognates and cognate words. Participants were asked to perform a same/different task when presented with these word pairs. Behavioral results demonstrated significant differences in how the language groups performed in each condition and with each word type, with bilinguals demonstrating greater variance in their response to Different trials. ERP results indicated an effect of language experience in the later time frames for frontal electrodes (P400), where bilinguals demonstrated a less robust response to Different trials for non-cognate words but performed on par with monolinguals for the cognate words. Examination of the parietal electrodes revealed a directionality effect for the N400, wherein the bilinguals demonstrated a significantly less robust response to different trials in which the accented version of the word was presented first. The observed LPC demonstrated a more robust response to non-cognate

Different trials by the bilingual participants when compared to both monolingual participants and to cognate trials.

Implications of this study point to a greater need for focus on phonological perception in second language learning as well as more emphasis on non-cognate vocabulary learning. In the future, a study that included analysis of perception and production of specific vowels within a more commonly occurring word set would give greater insight into which words and phonemes should be targeted in second language learning.

Appendix A.

Table A1: Word frequencies based on 51 million words.

Cognate	Word	Frequency (per 51 million words)	Non-cog	Word	Frequency
C	abyss	90	NC	begin	2906
C	arrest	3037	NC	bracket	32
C	attack	3853	NC	candle	409
C	battle	2155	NC	candy	1825
C	cancel	933	NC	canvas	216
C	commence	235	NC	children	8930
C	confess	808	NC	daddy	9439
C	cynic	56	NC	depict	27
C	demand	873	NC	dinner	10336
C	detect	261	NC	dismiss	279
C	differ	124	NC	dizzy	430
C	direct	1226	NC	evict	36
C	event	1345	NC	fender	130
C	exact	1154	NC	flatter	200
C	figure	6598	NC	forbid	436
C	fragment	96	NC	forget	14130
C	infect	62	NC	forgive	3917
C	magic	2687	NC	gamble	456
C	magnet	140	NC	gentle	844
C	mandate	76	NC	giggle	87
C	manner	588	NC	happen	12968
C	passport	534	NC	headlight	37
C	rebel	273	NC	healthy	1262
C	racket	379	NC	heaven	2887
C	second	14513	NC	hinder	37
C	system	4667	NC	matter	18900
C	talent	1332	NC	parrot	167
C	timid	77	NC	rattle	172
C	victim	2434	NC	ready	19778
			NC	regret	1384
			NC	sister	9207
			NC	tickle	245
			NC	until	15426
			NC	village	1712
			NC	willful	35

Chapter 5: References

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