Accepted for publication in Journal of Phonetics 3/14/2018

Neurophysiological indices of the effect of cognates on vowel perception in late Spanish-English bilinguals

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Abstract

It is well established that acquiring a second language (L2) later in life results in less accurate production and perception of speech sounds in the L2. Languages like Spanish and English have many common words (cognates) and similar sounds, learning how the combination of cognate status and sound similarity can affect processing and lexical access in an L2 is of interest to educators.

In the present study, fifteen monolingual English-speakers and 15 late Spanish-English bilinguals were presented with Spanish-English cognates and non-cognates. Event related potentials (ERP) were used to determine whether late L2-learners had more difficulty discriminating mispronunciations of vowels in English words that have Spanish cognates compared to words that do not have cognates. Behavioral results indicated effects of language background differences, but not cognate status, on participants' ability to discriminate mispronunciations of English vowels, with bilinguals showing poorer discrimination. ERP results revealed that cognate words facilitated L2 phonological processing as evidenced by a larger frontal positive component (P400) ERP effect, similar in amplitude to the P400 from monolinguals. Results suggest that cognate words facilitate not only vocabulary acquisition, but also speech processing, in adult L2 learners, and, thus, may also be useful as a tool for perceptual learning.

Key Words: bilingualism, cognates, event-related potential (ERP), second language acquisition, speech perception, vowel perception, Spanish-English

1. Introduction

Considerable research has demonstrated that attainment of native-like perception of second-language (L2) phonology is uncommon in adult learners of a second language (Flege, Munro, & MacKay, 1995; Levy, 2009; Oyama, 1976; Peltola, Kujala, Tuomainen, Ek, Altonen, & Näätänen, 2003). Perceptual abilities for L2 speech contrasts can be partially predicted from the relationship of the L1 and L2 phonological systems and their specific phonetic details (Best & Tyler, 2007; Bohn, Best, Avesani, & Vayra, 2011). However, these phonological relationships may not fully account for L2 perception patterns (Bohn et al., 2011). For example, a goal of the L2 learner is to recover meaning of L2 lexical (and syntactic) forms. Thus, it is important to understand L2 speech perception in the context of lexical processing and to incorporate such factors into models of speech perception?

The current paper examines whether the phonological relationship between translation equivalents (cognates versus non-cognates) modulates late learners' speech perception of vowel contrasts that are not phonemic in the first language (L1 This is of theoretical interest in that it addresses to what extent L1 lexical knowledge can modulate phonetic perception of L2 lexical forms. More specifically, it addresses whether L1 lexical forms that are phonologically similar to translation equivalents have a positive or negative effect on L2 speech perception. An additional question is whether neural correlates of phonetic and phonological processing of L2 lexical forms can provide insight on the processes leading up to the behavioral response used to evaluate speech perception.

1.1 L2 Speech Perception

Considerable research has focused on explaining and predicting which L2 speech contrasts will be difficult for naïve, non-native listeners or for L2 learners (Best & Tyler, 2007). The Perceptual Assimilation Model-L2 (PAM-L2; Best & Tyler, 2007, extension of PAM, Best, 1995) and Flege's Speech-Learning Model (SLM; Flege, 1995) are the two principal theoretical frameworks used to predict L2 speech perception.

The SLM makes predictions regarding the learnability of single sounds based on the learner's L1 and age acquisition. It predicts that learners will have the most difficulty forming new categories for sounds in the L2 that have a highly similar counterpart in their L1 and the difficulty increases with age. The PAM-L2 model focuses on perception of sound contrasts in the L2 and predicts poor discrimination of two L2 speech sounds that are assimilated into the same L1 phonetic category. PAM-L2 provides more fine-grained predictions regarding non-native speech perception in terms of assimilation patterns into the L1, whereas SLM focuses more on how age of acquisition and amount of experience and use affect L2 perception. However, there is great variation in the proficiency achievements of adult L2 learners, indicating that other factors need to be considered to more accurately model L2 speech perception.

The Automatic Selective Perception (ASP) model makes explicit the expectation that factors other than the relationship between L1 and L2 will influence L2 speech perception performance. This model was developed to account for differences in performance related to tasks and stimulus factors (Strange, 2011; Strange & Shafer, 2008). The ASP model posits that native-language speech perception is an involuntary process, whereby listeners use Selective Perceptual Routines (SPRs) to automatically select the most relevant phonetic features. These SPRs reflect language-specific weightings of relevant features that allow for the recovery of phoneme identity. The ASP model predicts that L2 speech contrasts that are not clearly distinct in the L1 will need attentional resources for robust L2 speech perception. Thus, as task difficulty increases, as in perception of connected speech or speech perception in noisy situations, L2 perception becomes more difficult because L2 listeners will fall back on L1 SPRs.

1.2 Lexical access in second language speakers

Similarities in L1 and L2 lexical items can facilitate L2 acquisition (Dijkstra, Grainger, & van Heuven, 1999). In particular, phonological similarity of an L1 word and an L2 word that share similar meanings can have a positive effect on L2 learning and processing. Words that have a shared meaning and origin and similar phonology across the L1 and L2 are called cognates. For example, English *elephant* and its Spanish equivalent, *elefante* are cognates. These words are characterized by similar speech sounds at a phonological level (and, indeed, have the same Latin origin), even though they differ somewhat in syllable structure and phonetic detail. Late L2 learners (i.e., those learning a language after puberty) demonstrate a higher level of proficiency for L2 words that have L1 cognates (de Bleser et al., 2003; de Groot & Nas, 1991). These L2 cognate words show facilitated lexical processing for the L2 learner, seen as more rapid access to word meaning; both semantic similarity and phonological similarity between L1 and L2 words show a benefit (Dijkstra et al., 1999; Dijkstra, Miwa, Brummelhuis, Sappeli, & Badyan, 2010; Gollan & Acenas, 2004). One suggestion regarding the representation of L1 and L2 cognate pairs is that they share more connections at both the lexical and phonological levels (Costa, Sanesteban, & Caño, 2005). Despite the facilitation in access to lexical meaning, cognates pose particular challenges for L2 learners with regard to accurate pronunciation (Derwing, 2003). Specifically, several studies have shown less accurate production of cognate than non-cognate L2 words (Nip & Blumenfeld, 2015; Amengual, 2012).

It is also important to recognize that successful lexical access requires somehow suppressing or inhibiting the non-target lexical item. Studies have found that bilinguals access both of their languages during the lexical access process (Dijkstra et al., 1999, Dijkstra & van Heuven, 1998), but at some point in processing, non-target words need to be inhibited (or the target item needs to accrue above-threshold level activation). Green (1998) proposed an inhibitory control model (ICM) that assists the individual in inhibiting activation of words in the non-target language in a reactive manner. In the ICM, words in the non-target language require a higher level of activation because the threshold is set higher by a mechanism outside the lexical selection process.

The ICM does not propose an account of lexical access with regards to cognate words. Cognate words show greater facilitation than non-cognate words (which show limited facilitation effects) in cross-language priming tasks (Sánchez-Casas, Davis, & Albea, 1992). Facilitation would result in greater activation for cognates due to phonological similarity, which would allow for reaching the threshold for lexical access more rapidly. Alternatively, cognate words in the non-target language may not be inhibited to the same extent as non-cognate words. For either explanation, the existence of an L1 cognate might cause interference for accessing the correct phonological and phonetic form in the L2. More specifically, failure to effectively inhibit L1 lexical items could result in perception or production of an L2 cognate in a more L1-like manner. Thus, in accessing English *elephant*, its Spanish translation *elefante* would be activated, and remain activated (and possibly be selected) because of strong connections between the L1 and L2 lexical entries. In this case, the selected lexical item might result in phonetic realizations that match the L1. In contrast, the English word *chair* and its Spanish equivalent *silla* would share connections only in terms of semantic (and syntactic) information; this would result in less interference from the L1 in selecting L2 *chair* because the Spanish translation equivalent, *silla* can more easily be inhibited (or more easily be maintained at a higher threshold). The question here in relation to connectionist models such as the ICM is whether the phonological status of translation equivalents influences the lexical access process, either by influencing the activation level of the non-target lexical item, or, perhaps as a result of the L1 and L2 forms sharing a lexical entry.

1.2.1 Cross language effect in vowel perception

The English vowel system contains 12 true vowels, and is larger than the vowel systems of most other languages, with many vowels separated by relatively small spectral distances (Hillenbrand, Getty, Clark, & Wheeler, 1995). Success in acquiring new vowel contrasts is highly dependent on the age at which the L2 is acquired (Baker & Trofimovich, 2005). Similarities and differences in the two phonological systems are also factors in L2 speech perception and production (e.g., Flege, Bohn, & Jang, 1997, Flege, Munro, & Fox, 1994, Strange, et al., 1998). Language experience influences discrimination of English vowel contrasts (Flege et al., 1997) but even experienced listeners can continue to have difficulties with vowel contrasts that are present only in the L2 (Levy & Strange, 2008). In addition, accurate L2 vowel perception has been linked to production accuracy (Flege, Mackay, & Meador, 1999; Levy & Law, 2010).

American English has at least 11 distinct vowels, but Spanish has only five vowels. Both Spanish and English vowel inventories include a high front vowel /i/, as in the English word *eat*, and a mid-front vowel /e/, as in English *ate*, although the Spanish phonetic realization of these is somewhat different. English has three additional front vowels that are not found in Spanish; these include a high-front lax vowel, /ɪ/ as in *bit*, another mid-front lax vowel /ɛ/, as in *bet* and a low-front vowel, /æ/, as in *bat*. In Spanish, the lax /ɛ/ does not contrast meaning with /e/, but rather is realized as an allophone of /e/ (e.g., in the words *pena/pain* [e] and *perro/dog* [ɛ]). Lastly, the Spanish inventory includes a low-central vowel, /a/ as in *hola*, whereas English includes the low-back /ɑ/ as in *hot* (MacDonald, 1989).

English vowels will, at least initially, be perceived by native Spanish late learners of English as variants of one of the five Spanish vowels and be categorized into existing L1 vowel categories (Fox, Flege, & Munro, 1995). Spanish L2 learners of English may produce or perceive words that differ minimally by one (vowel) phoneme (i.e., minimal pairs) in English as identical words as has been previously shown with Spanish-Catalan bilinguals using words pairs that only differed in a Catalan vowel (Pallier, Colomé, & Sebastián-Gallés, 2001). These words may share a single lexical representation (Sebastián-Gallés et al., 2005; Sebastián-Gallés & Soto-Faraco, 1999). For example, Spanish-English bilinguals may pronounce the word *racket* (/rækɪt/) with a more Spanish-like vowel, resulting in the English word *rocket* (/rɑkɪt/). Late Spanish speaking learners of English show difficulty perceiving the difference between /ɑ-æ/ contrast and /i-ɪ/ contrast (Barrios, Jiang & Idsardi, 2016). In fact, even English dominant bilinguals demonstrate differences in their production of the *rocket-racket* contrast when compared to monolingual English speakers (Casillas & Simonet, 2016). The current study focuses on how Spanish L2 learners of English perceive and process English phonological information (i.e., vowel contrasts) and whether this perception is affected by the cognate status of words.

1.3 Event-related potentials (ERPs) to lexical and phonological processing

Event Related Potentials (ERPs) recorded to speech processing are a useful means for examining the timing of processes leading up to a behavioral response. ERPs are voltage potentials of the electroencephalogram (EEG) recorded at the scalp via electrodes, and that are time-locked to an event or stimulus of interest. The EEG reflects the summation of electrical activity that is the consequence of neural firing (from post-synaptic potentials), largely emanating from cortical regions. Averaging across many trials time-locked to the same stimulus allows the processes (signal) of interest to be observed, because activity that is not time-locked is random and approaches zero in the averaging process as the number of trials increases. ERPs are described in terms of the latency from the point of time-locking (e.g., stimulus onset), the amplitude of peaks or of differences between conditions, and by location/topography (e.g., Cz, at the top of the head). These measures can be used to infer the timing of processes underlying speech perception and lexical access, including obligatory auditory-phonetic processing, phonetic discrimination, phonological discrimination and meta-linguistic processes related to task decisions.

ERP patterns (or components) that are of interest to the current study include the N400, the Late Positive Component (LPC), the P400/ PMN, and the late frontal positivity. The N400 component is sensitive to lexical access factors and to factors reflecting integration of semantic information into a prior context. This component is a negative deflection that peaks between 200 and 600 ms after a target stimulus' onset and is largest over superior central-parietal and posterior scalp sites (Schoonbaert, Holcomb, Grainger, & Hartsuiker, 2011). Greater difficulty accessing a word's meaning or integrating the word meaning into the prior context results in increased negativity of the ERP around about 400 ms post-stimulus onset relative to a control condition (Kutas & Federmeier, 2011). Phonological or semantic priming of a word reduces difficulty in lexical access (and semantic integration). Therefore, priming by an identical word form will attenuate the N400 effect compared to priming by a word form that includes a phonological difference (Praamstra, Meyer, & Levelt, 1994; Holcomb & Neville, 1990).

Cross-linguistic and L2 studies using an N400 design suggest that it is an indirect measure of phonological difference, and will only show a difference between words that differ by one phoneme if the two forms differentially activate lexical entries (e.g., Sebastián-Gallés, Rodríguez-Fornells, de Diego-Balaguer, & Díaz, 2006). For example, Sebastián-Gallés, et al. observed an increase in N400 to non-words that differed from real words by one vowel contrast (e.g., real word *cadira* (meaning chair), non-word *cadura*), when there was little chance that the non-word would be interpreted as a mispronunciation of a real word for bilingual Spanish-Catalan listeners. However, for a finer contrast of /e/ versus /ɛ/, which was phonemic only in Catalan (but shown to be problematic for Spanish-dominant speakers), they did not observed increased N400 for non-words for bilinguals, even for those listeners who were dominant in Catalan. The authors suggested that the bilingual environment in Barcelona led to both the Spanish- and Catalan-dominant listeners treating the “mispronunciation” (i.e., /e/ for /ɛ/ or /ɛ/ for /e/) as allowing lexical access to the Catalan word because Catalan listeners had become accustomed to the Spanish pronunciation of /ɛ/ as /e/. This lack of an N400-effect was found despite other evidence that Catalan listeners were aware of the “mispronunciations”. Other studies using words that were clearly nonsense words have not observed N400 effects (e.g., Praamstra, et al., 1994; Wagner, Shafer, Martin, and Steinschneider, 2012). These findings support the argument that the N400 effect is primarily an index of lexical access (and semantic integration), and, thus, it serves as an indirect index of phonological differences.

The LPC is a posterior positivity that follows the N400 effect. This component appears to reflect an evaluation process. In several studies it has also been shown to index phonological differences, with individuals demonstrating a greater positivity to a greater phonological difference (e.g., Dehaene-Lambertz, Dupoux, & Gout, 2000; Wagner et al., 2012). The LPC is largest over parietal electrode sites and appears to be modulated by (and possibly require) the participant’s response to a stimulus (e.g., a same/different behavioral response) rather than indexing processing of the physical properties of the stimulus itself (Linden, 2005). The LPC may be related to the P3b component, which is elicited during detection of a non-linguistic stimulus change in the auditory or visual modality (Squires, Squires, & Hillyard, 1975).

The P400 is a positive-going peak at frontal sites that peaks around 400 ms. This P400 peak was shown to be modulated by both acoustic-phonetic and phonological factors in a study examining neural discrimination of native and non-native syllable structures (Wagner et al., 2012). In this study, English and Polish speaking listeners were presented with non-words that included the /pt/ cluster or this cluster with an epenthetic schwa (/pt/ versus /pət/). The /pt/ cluster is legal in initial position in Polish but not in English. The pairs of non-words were either the same phonological forms but different tokens, (e.g., different exemplars of ptola-ptola) or different phonological forms (e.g., ptola-pətola). The participants were asked to judge whether the second word of a pair had two or three syllables. The authors observed greater positivity at frontal sites around 400 ms (thus, the P400 name) in English and Polish listeners when the second word differed from the first, even though only the Polish listeners were accurate in syllable judgments. (Generally, English speakers heard all words as having 3 syllables.) However, the P400 peak amplitude was earlier for the Polish than the English group (suggesting superior performance in discrimination), indicating that linguistic factors (i.e., language background) also modulate the P400. In addition, only the Polish listeners showed accurate syllable number judgments and an LPC response, indicating discrimination of the onset types (Wagner, et al., 2012). This P400 effect may reflect the same processes as the phonological mismatch negativity (PMN) found in sentence-processing studies (e.g., Connolly & Phillips, 1994). In several studies, an increased negativity at fronto-central sites (the PMN) was found to an unexpected phonological onset in sentences where the meaning of prior words highly constrained the expected word (Connolly & Phillips, 1994; D’Arcy, Connolly & Crocker, 2000) (cite PMN studies here!!!). For example, in the sentence “He put his dishes in the kitchen bath” the ERP to the onset [b] is more negative around 200 ms post onset than the ERP to *sack* or *sink* in "He put his dishes in the kitchen sack/sink". The negative response to *bath* is thought to be due to the listener's expectation of *sink*. N400's modulation is seen for both *bath* and *sack* relative to *sink*, at a later time. The PMN was interpreted to indicate some level of phonological awareness in the early stages of word recognition. These findings indicate that the P400/PMN is a useful measure in an ERP design presenting prime and target word forms that differ phonologically.

1.4 The current study

This study examined whether cognate status of English words in Spanish-English bilinguals modulated phonological processing of these words. A cognate was defined as a word that shared similar meaning and phonology across Spanish and English (Costa, Caramazza, & Sebastián-Gallés, 2000; Costa, Santesteban, & Caño, 2005). Target words with the vowel phonemes /ɪ/, /ɛ/, and /æ/ were examined because these three vowels are not phonemes in Spanish and are often assimilated into the Spanish phoneme categories,/i/, /e/, and /ɑ/ respectively, by Spanish learners of English (Hammond, 1986; MacDonald, 1989; Flege, Bohn, & Jang, 1997). Thus, lexically different words in English (e.g., rocket vs. racket) could be perceived as identical words by Spanish-English bilinguals.

Late learners of English were tested because these listeners often continue to have difficulty with L2 phonology, even after achieving good proficiency at other levels of language (Flege et al., 1999). Participants were actively engaged in a discrimination task using cognate and non-cognate words in English. ERPs were used to test whether cognate status affected L2 processing because these measures reveal the underlying neural processes that lead up to the behavioral response. More specifically, ERPs allow for a fine-grained analysis of the understanding of how bilingual listeners process L2 speech.

The questions addressed were (1) whether bilingual (BL) late L2 learners of English would have greater difficulty detecting mispronunciations of L2 vowels in English words that have Spanish cognates, compared to those that do not have Spanish cognates, and (2) how neural measures of discrimination would relate to the learners' language experience (monolingual vs. bilingual) and behavior. Discrimination was measured using behavioral discrimination accuracy and the ERP measures, PMN, N400, LPC, and P400.

We hypothesized that late Spanish-English bilinguals would assimilate the American English (AE) vowels /ɪ/ and /i/ to their Spanish /i/ category, AE /ɛ/ and /e/ to their Spanish /e/ category (Hammond, 1986; MacDonald, 1989; Flege, Bohn, & Jang, 1997) and /æ/ and /ɑ/ to their Spanish /a/ category (Flege, 1991; Hammond, 1986), although some Spanish speakers of AE may also collapse the /ɛ/ and /æ/ phonemes into one category because Spanish includes neither lax nor low front vowels (MacDonald, 1989).

BL participants were expected to demonstrate poorer discrimination between correctly and incorrectly pronounced vowel pairs (e.g., /e/ vs. /ɛ/) in an English word. In addition, we predicted discrimination would be poorer when Spanish had a cognate for the English word than when Spanish did not. Knowing that cognate words might be more interconnected than non-cognate words at a lexical level (Costa, Santesteban, &

Caño, 2005); L1 words might not be sufficiently inhibited when accessing the L2 cognate (Shook & Marian, 2013), and lead listeners to select the cognate lexical entry regardless of mispronunciation. Evidence of poor perceptual discrimination or access to the lexical item, regardless of mispronunciation, would be reflected in lower accuracy of behavioral responses. For ERPs, assimilation of the mispronunciation into an L1 category would be seen as no difference in neural responses that reflect phonological processes between same a different pairs early in time. We hypothesized that the P400 would be sensitive to phonological, but not lexical factors. In contrast, poor discrimination due to lexical factors would be observed in the ERPs reflecting lexical access (N400 and LPC). Specifically we anticipated that the N400 and LPC would be smaller in response to the cognate words for the BL group only.

2. Method

2.1 Participants and Language Measures

Data were collected from 18 native monolingual (ML) English speakers and 21 BL speakers. Three ML participants were excluded from the final sample due to an ERP acquisition error (one), poor ERP signal-to-noise ratio (one), or discovery that the participant did not fit the criteria for the monolingual group (one). Six BL participants were not included in the final study due to ERP acquisition error or corrupted data (three), poor ERP signal-to-noise ratio (two), or information on the language background questionnaire indicating exposure to English before the age of 14 years (one).

Participants included in the final analysis were 15 native monolingual English speakers (mean age = 28 years, SD = 6.0 years, range = 21-37 years) and 15 late Spanish-English bilinguals (mean age = 33 years, SD = 5.2 years, range = 25-42 years). BL participants were from a variety of Spanish-speaking countries and spoke only Spanish and English. Their exposure to English had begun after the age of 14 years (mean age = 22 years, range =14 to 36 years). Participants with a hearing loss, proficiency in a third language, and/or history of speech-language disorders were excluded from the study. All listeners passed a hearing screening at 25 dB at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz.

Language measures were administered to ensure that all participants had a vocabulary size within the standard range in their L1. Before ERP testing began, the bilingual participants were asked to complete a language background questionnaire, which asked questions about language use in education and daily use of each language. This group was also asked to complete a 15-question English grammar test. Lexical knowledge of English was evaluated by using items from the Peabody Picture Vocabulary Test (PPVT; Dunn & Dunn, 2007), which is a standardized test normed on monolingual English speakers. The PPVT is constructed beginning with higher-frequency/higher familiarity words. With each subsequent item, the frequency/familiarity decreases. When administered to a native speaker of English, the test is terminated after the speaker scores incorrectly on six items in a row. The last correct item is used to calculate a language score (adjusted for age). Lexical knowledge was estimated in a different manner, as late bilingual leaners of are not expected to acquire lexical items in to the same order as a native speaker, undermining the validity of the test. Thus all test items between 73 and 144 (words expected to be acquired by 12-16 year old monolingual English speakers) were administered and the English lexical knowledge was estimated by calculating the number of incorrect (from a total of 72 items). The test was always administered before the ERP session. After ERP testing, the Test de Vocabulario en Imágenes de Peabody (Dunn, Lugo, Padilla, & Dunn, 1986 [TVIP]), which is the normed Spanish version of the PPVT, was administered to the late-bilinguals to assess lexical knowledge in their L1. ML participants were administered the PPVT and all performed within the standard range (mean = 108, SD = 10). Both groups were asked to complete a 20-question vocabulary test (multiple choice) before the ERP task to assess knowledge of the target words used in the study. Language testing results and more information regarding each participant is provided in Appendix A.

2.2 Stimuli

The stimuli included recordings of 28 Spanish-English cognates and 33 non-cognates (five cognates were excluded from the study due to questionable cognate status or poor recording quality). All words were coded for frequency of occurrence in a database of 51 million words from the SUBTLEX (US) Corpus (Brysbaert & New, 2009). Eighty percent of the words had a frequency per million words (FPMW) of more than two (up to 381 for the non-cognate "ready"). A two-tailed t-test revealed no statistically significant difference in frequency between the cognate words and the non-cognate words (t (59) =1.71, p =*.092*). Experimental vowels occurred in stressed positions to maintain a full vowel quality. The target stressed vowel in both cognates and non-cognates occurred 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/) (MacDonald, 1989). (Please see Appendix B for a full list of stimuli.)

Words were produced in English by a native New Yorker, once with the correct target vowel, and a second time with a mispronounced target vowel. The mispronounced vowel and the target vowel were contrasts that are not phonemic in Spanish. For the words with mispronounced vowels, the /ɪ/ was replaced by an /i/, the /ɛ/ was replaced by an /e/, and the /æ/ was replaced by an /ɑ/. For example, the mispronunciation of the non-cognate *sister* was produced with the /i/ (i.e., "seester"). Similar substitutions were made for cognate words such as *magic* (e.g., /mæʤɪk/ vs. /mɑʤɪk/). The design of this study was motivated by that of Sebastián-Gallés, Rodríguez-Fornells, de Diego-Balaguer, and Díaz (2006), in which two groups of bilinguals were presented with words that differed in a vowel contrast that existed in only one of their languages.

In the present study, a late bilingual English-Spanish female speaker (whose L1 was English) with phonetic training produced the words. The choice to use mispronunciations by an English L1 speaker was made because piloting showed that it was difficult for a Spanish L1 bilingual speaker to isolate the mispronunciation only to the target vowel. Specifically, the Spanish-dominant bilingual would produce the entire word with Spanish phonology, particularly for cognates. The words were recorded four times each in a carrier phrase (*I said* _______ *this time*). The best production (clear target vowel) for each word was selected as the experiment stimuli (generally the second or third repetition). The mean frequencies and standard deviations for F1 and F2 of each of the standard (i.e., /ɪ, ɛ, æ/) vowels and the mispronounced vowels (i.e., /i, e, ɑ/) can be seen in Table 1. T-tests were performed to compare the mean formant frequencies of contrasting vowel pairs (i.e., i/ɪ, e/ɛ, ɑ/æ). There was a significant difference in mean values of both F1 (t (24)=10.4, $p < .0001$) and F2 (t (24)=-6.86, $p < .0001$) for the e/ɛ contrast. There was also a significant difference in the mean values of both the F1 (*t* (22)=5.71, *p* < .001) and F2 (*t* (22)=-9.66, *p* < .001) for the i/ɪ contrast. There was a significant difference in the mean values of the F2 for the ɑ/æ contrast; t (16)=p < .001. However, there was not a significant difference in the mean values of the F1 for the ɑ/æ contrast; t (16)=p = 0.28. All contrasts were significant at the p < .001 level except for the F1 of the ɑ/æ contrast. These vowels are closely related to the values in Hillenbrand et al., (1995) for female AE speakers. The /e/, /æ/ and /ɑ/ have lower F2 values than those in Hillenbrand et al. (1995), which may in part be due to the speaker being a native New Yorker as opposed to the Midwestern dialect of the speakers in the Hillenbrand et al. study. Four native speakers of American English judged the stimuli as good exemplars of the target vowels. Stimuli were normalized for intensity using Sound Forge 8.0 (Sony). All words were measured for target vowel onset time to allow for ERP time-locking to vowel onset for later processing. Stimuli ranged in length from 517 ms to 880 ms. Stimuli were delivered at an average intensity of 75 dB SPL.

Table 1.
Means (in Hz) and standard deviations (SD) for vowels used in the experimental stimuli. Contrasts are numbered to indicate vowel pairs used in experimental stimuli.

Contrast	Vowel	Type	F1 Mean	F1 SD	F2 Mean	F2 SD
1	ɛ	Standard	755	93	1766	220
2	æ	Standard	772	190	1636	162
3	ɪ	Standard	492	35	2115	126
1	e	Mispronounced	469	44	2556	288
2	ɑ	Mispronounced	859	138	1276	98
3	i	Mispronounced	374	60	2799	202

Word pairs used in the study were classified as Same trials (i.e., two correctly or two incorrectly pronounced words) or as Different trials (i.e., the correctly pronounced word paired with the mispronounced word).

2.3 ERP and Behavioral Design

The study used a priming design. Word pairs included a prime (1st) word, followed by a target (2nd) word in one of the following four conditions: A standard prime followed by a standard target of the same word (e.g., /sɪstɚ/-/sɪstɚ/), a standard prime followed by a mispronounced target of the same word (e.g., /sɪ̱stɚ/-/si̱stɚ/), a mispronounced prime followed by a standard target of the same word (e.g., /si̱stɚ/-/sɪ̱stɚ/) and a mispronounced prime followed by a mispronounced target of the same word (e.g., /si̱stɚ/-/si̱stɚ/). Each condition was used with both cognate and non-cognate words. The word pairs were randomized, with the constraint that 17 items occurred between repetitions of the same target pair (e.g., /si̱stɚ/-/sɪ̱stɚ/ in any of the four orders). After being randomized, the stimuli were divided into 10 blocks of 80 pairs with breaks between each block. Approximately 200 pairs were delivered for each of the four conditions, but it should be noted that slightly fewer were presented for the cognate Same pair condition (170 pairs) because one of the 8 blocks was incorrectly balanced (non-cognate-Same pair 207; cognate Different pair: 203; non-cognate-different pair 220).

This occurred because one block in the stimulus delivery software (e-prime) had an error in it, and was replaced with a different block. This difference in number for condition, however, did not affect the outcome as all participants received the same treatment and there were a sufficient number of trials for each condition for good signal-to-noise ratio. Pairs of stimuli were separated by an 800 ms inter-stimulus interval (ISI). This ISI was chosen as it was thought to be long enough to avoid acoustical processing of word pairs (Fox, 1984; Pisoni & Tash, 1974.)

All participants took part in a behavioral discrimination task during the ERP study. They were provided with a response box and 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. Participants were allowed 1,500 ms after the offset of the target word to respond. The next trial was initiated immediately after the response or at 1,500 ms post stimulus if no response occurred. Fifty-three percent of the word pairs included a mispronunciation of one of the three target vowels (/ɪ,ɛ,æ/) (Different pairs). Forty-seven percent were word pairs in which the same lexical item was used for both prime and target (Same pairs). Same pairs consisted of both identical tokens and different tokens of the same word. There were slightly more Different than Same pairs because one word list was rejected from the study and replaced by a different list at the onset because of error. The same set of lists were used for all the following participants.

2.4 Procedures

Participants were seated in a soundproof room to begin electrophysiological testing, which lasted approximately 40 minutes (see below for ERP setup). Stimuli were presented via two speakers set at one meter away at 45-degree angles from the participants. Each participant was given oral and written instructions to complete the same/different task starting with a 12-trial practice with feedback. After the practice trials, the monitor was changed from a screen with feedback to a screen that showed a large picture of a shape (e.g., heart, circle, or cube) with a dark-colored background. (The shape was presented to provide a focus for the eyes in order to reduce eye movements during the experiment). Participants were instructed to look at the shape on the screen during the study. The order of block presentation was randomized. Stimulus delivery was controlled by E-prime software version 1.1. Twenty-eight participants completed 10 blocks (800 word pairs). Two participants completed only 9 blocks (720 word pairs) due to fatigue.

ERPs were recorded to speech stimuli presented in an AX task, in which participants judged whether the second word (X) of a pair of words was the same as or different from the first (A). For different trials, one of the words was a mispronunciation of the target vowel (/ɪ/ pronounced as English /i/, /ɛ/ pronounced as English /e/ or /æ/ pronounced as English /ɑ/). Same trials consisted of pairs of words consisting of two identical, correctly-pronounced English words or two identical, mispronounced English words. Different trials consisted of one correctly-pronounced and one mispronounced English word (presented in two orders) resulting in a total of four conditions (see Table 2).

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

Trial Type	**Number of Occurrences**	**Mean Occurrences per block of 80**
Cognate-Cognate Same	170	36.53
Cognate- Cognate Different	203	31.27
Non-cognate-Non-cognate Same	207	37.63
Non-cognate-Non-cognate Different	220	40.18
Total	800	

2.5 ERP recording

The electroencephalogram was recorded at a 250 Hz sampling rate and bandpass filter from 0.1-30 Hz using Netstation version 4.1.2and Geodesics amplifiers (Electrical Geodesics, Inc.) Data were collected from 65 electrode scalp sites using a Geodesics net. The vertex (Cz) was used as a reference during data collection. 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 in which the target vowel was present in the second syllable. The following analyses use the onset of the word for words with first syllable stress (e.g., magnet), and the onset of the syllable for second syllable stress (e.g., abyss).

2.6 ERP Analysis

The EEG was epoched from 200 ms prior to the onset of the stimulus to 800 ms following stimulus onset. To clean the data, noisy epochs (trials) were removed. Artifact rejection was set at +/− 100 μV to exclude epochs for which greater than 20% of the electrodes channels exceeded this limit. Channels that showed artifact on more than 20% of the trials for a participant were replaced by spline interpolation form surrounding channels using BESA (Brain Electrical Source Analysis). Data were baseline corrected using the 100 ms interval prior to stimulus onset. ERPs were then averaged and re-referenced to an average reference. The mean number of epochs per average for the bilingual group was 106 (SD = 29) for cognate-Same condition, 139 (SD = 35) for non-cognate-Same condition, 137 (SD = 34) for the cognate-Different condition, and 152 (SD = 37) for the non-cognate-Different condition. The mean number of epochs per average for the monolingual group was 130 (SD = 18) for the cognate-Same condition, 171 (SD = 23) for the non-cognate-Same condition, 169 (SD = 21) for the cognate-Different condition, and 191 (SD = 23) for the non-cognate-Different condition.

Several regions were selected that were expected to show the ERP components of interest. Electrodes included in each region were highly correlated (Pearson's $r > 0.8$) across the time interval of interest, justifying collapsing the data. Previous priming studies have demonstrated an increased positivity around the Fz electrode and a decrease in negativity in parietal electrodes close to Pz (Pickering & Schweinberger, 2003). We used these two electrodes as guides to form two regions of interest. The first region (henceforth, Parietal model) was comprised of electrodes over the parietal region that correlated highly with site 34 (near Pz in the 10-10 international system of electrode placements; see Figure 1); site 34, site 38 (between Oz and Pz), site 41 (near P4), and site 42(near P2); data were averaged across these sites to test modulation of the N400 priming effect (Pickering & Schweinberger, 2003) and the LPC. The other region of interest (henceforth, the Frontal model) was comprised of sites over fronto-central regions that correlated highly with site 4 (near Fz): site 4, site 5 and site 55 (near Cz), site 53, (near C4), site 57 and 62 (near F4), site 61(near F8). These sites were averaged and used to test modulation of the PMN and P400. (See electrode placement in Fig. 1.) This method can reduce the contribution of noise as well as the effects of inter-subject variations (Yu, Shafer, & Sussman, 2017).

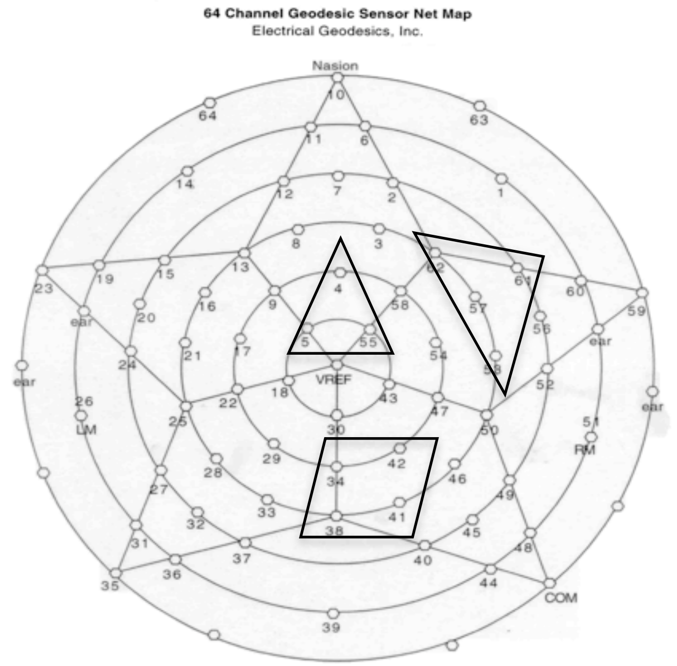


Fig. 1. Map of relative eletrode placement for Geodesics 64 channel net, with channel 65 as VREF. Parallelogram indicates the four parietal model electrodes. The triangles represent the seven frontal model electrodes.

2.7 Statistical Analysis

For the behavioral data, accuracy (percent correct) was calculated and served as the dependent measure and was examined using mixed-model regressions. As participants were not asked to respond as fast as possible, reaction time data were not analyzed.

For the ERP analysis, the amplitude of the Frontal or Parietal model served as the dependent measure. A mixed-model regression analysis 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. Participant was used as a random effect and all other factors as fixed effects. We used R (R core team, 2013) and the lme4 package (Bates, Maechler, Bolker, & Walker, 2013) with the Alkaike Information Criterion (AIC) to compare the fit of competing models. The amplitude of each model (Frontal and Parietal) was averaged across 80 ms intervals starting from 200 ms up to 800 ms post-stimulus onset, except the last interval, which was 40 ms (Schoonbaert et al., 2011). This reduced the data to seven time points. The selected time frames were consistent with previous studies examining the PMN, N400, LPC, and P400 measures (Connolly & Phillips, 1994; Kutas & Federmeier, 2011; Linden, 2005; Wagner et al., 2012). The time frames were further collapsed for analyses if adjacent intervals were highly correlated. For example, the amplitude of the 520-599 ms and 600-679 ms intervals were highly correlated and were, thus, collapsed.

3. Results

3.1 Behavioral discrimination

Behavioral accuracy was calculated from the participants' responses of either Same or Different to the presented word pairs. ML participants revealed an overall mean accuracy of 92% (SD = 3.5%) and the BL participants showed a mean accuracy of 82% (SD = 9.7%). Statistical comparisons revealed a significant difference between groups in performance on both the Same (t (28) = 4.04, p = 0.0014) and Different (t (28) = 3.28, p = 0.0059) conditions (see Table 3a and 3b for accuracy scores).

Table 3a
Behavioral data results in % accuracy for each of the four experimental conditions.

	ML	BL
Same-Cognate	93	90
Same-Non-Cog	93	88
Diff-Cognate	89	76
Diff-Non-Cog	91	76

Table 3b
Behavioral data results in % accuracy for each of the three vowel contrasts.

Group	Vowel Contrast	Mean %
BL	e/ɛ	85
BL	ɑ/æ	81
BL	i/ɪ	82
ML	e/ɛ	91
ML	ɑ/æ	92
ML	i/ɪ	91

A mixed effects binary logistic regression analysis was used to investigate the relationship between ML/BL status and percent accuracy and whether accuracy could predict language background. We used participant as a random effect and percent accuracy as a fixed effect, with Group, Type, and Condition as factors. Our analysis revealed that all main effects were statistically significant ($p < 0.001$) as were the interactions of Group x Type ($z = -3.1$, $p < 0.01$) and Group x Condition ($z = -4.8$, $p < 0.01$); however, no three-way interaction of Group x Type x Condition ($z = 0.9$, $p = 0.34$) was found. Examination of the Group x Condition interaction showed that Different trials provided more of a challenge to bilinguals than to monolinguals. Specifically, the bilinguals had more difficulty detecting the mispronunciations (i.e., they were more likely to give an answer of Same). Examination of the Group x Type interaction demonstrated the BLs were more accurate when identifying Same or Different trials when presented with cognates versus non-cognates.

An examination of the raw accuracy scores revealed that five out of 15 BLs were within one standard deviation of the mean (4%) of the ML group and another four BLs had accuracy scores within two standard deviations of the mean for the MLs. This indicates that there was a great variance in accuracy in the BL group and at least some of the BLs had accuracy scores similar to the MLs, while six of the BLs had scores at least two standard deviations below the mean of the MLs.

3.2 Electrophysiological Results

3.2.1 Frontal Model

Figure 2 shows the Grand Average ERPs at the frontal sites (averaged across seven sites) for the two groups (ML and BL), two types (non-cognate and cognate) and two conditions (Same and Different). Both groups show greater positivity of the ERP to the Different trials, but this appears to emerge earlier in the ML compared to BL group. Mixed effects modeling was performed on successive time intervals to determine whether group, type or condition significantly affected ERP amplitude.

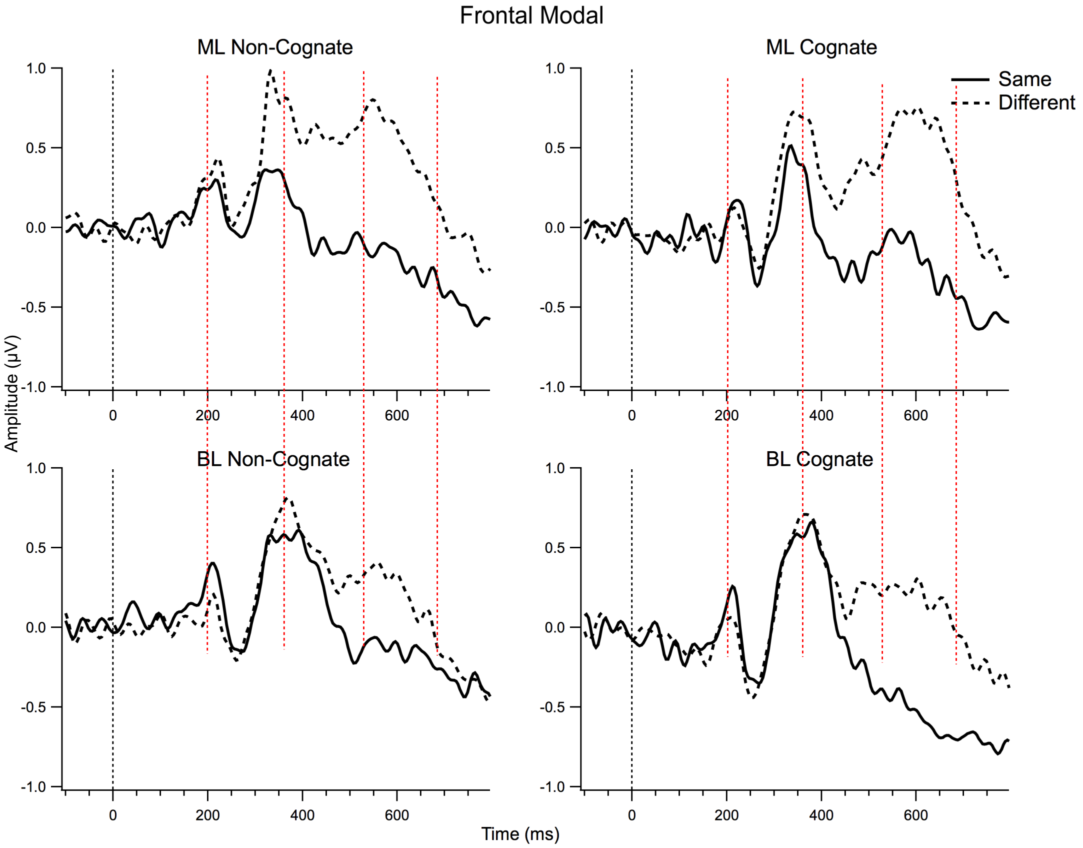


Fig. 2: ML (top graphs) and BL (bottom graphs) Grand Mean ERPs to same and different trials for non-cognates (left graphs) and cognates (right graphs) in frontal model. The vertical red dashed lines show the time intervals used in the analyses.

3.2.2 Early Frontal Positivity (PMN)

The early time frame from 200 to 359 ms was examined for the PMN component to determine whether the ERP response was modulated by condition (Same, Different) or Type (cognate, non-cognate). Results revealed that the best model included a Group x Condition interaction (see Table 4). Specifically, the ML group showed a more positive response to the Different compared to the Same condition, (mean difference = 0.14 μV, SD = 0.36 μV), whereas the BL group showed little difference between conditions (mean difference = 0.04 μV, SD = 0.32 μV) (see Fig. 2 above.) The three-way interaction of Group x Type x Condition did not significantly improve the model (t = 1.05, *p* = 0.29).

Table 4. Mixed model results for Frontal electrodes from 200-359 ms post-stimulus. The intercept estimate is the ML Same non-cognate condition (in μVs).

Frontal 200-359 ms			
	Estimate	**Std. Error**	**t value**
(Intercept)	0.207488	0.134906	1.538
Condition	0.194975	0.028290	6.892**
Type	-0.106923	0.028290	-3.780**
Group	0.027996	0.190786	0.147
Condition x Type	-0.106066	0.040008	-2.651
Condition x Group	-0.208650	0.040008	-5.215**
Type x Group	-0.002041	0.040008	-0.051
Condition x Type x Group	0.059616	0.056579	1.054

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

3.2.3 P400 Frontal Positivity

The time intervals from 360 to 519 ms for the frontal model were examined with group, condition and type as factors. The mixed model analysis revealed a main effect of condition, in which the Different condition was more positive than the Same condition. The best fit model also revealed interactions of Condition x Type, Condition x Group and a three-way interaction of Condition x Type x Group (see Table 5). Essentially, the BL group showed less of a difference between the Same and Different conditions than the ML Group; the non-cognate condition showed a larger condition effect (specifically, greater positivity to the Different condition), but primarily for the ML group (Non-cognate mean difference = 0.59 μV, SD = 0.67; cognate mean difference = 0.44 μV, SD = 0.69). The BL group showed little difference between the word types (non-cognate mean difference = 0.21 μV, SD = 0.61; cognate mean difference = 0.24 μV, SD = 0.73).

In summary, the MLs showed a significantly larger condition effect (increased positivity to the Different condition) than the BL group. The cognate status only affected the response for the ML group, with a larger positivity found for non-cognate than cognate trials.

Table 5. Mixed model results for Frontal electrodes from 200-359 ms post-stimulus. The intercept estimate is the ML Same non-cognate condition (in μVs).

Frontal 360-519 ms			
	Estimate	**Std. Error**	**t value**
(Intercept)	0.05922	0.15879	0.373
Condition	0.58865	0.02892	20.352**
Type	-0.12561	0.02892	-4.343**
Group	0.27105	0.22457	1.207
Condition x Type	-0.14374	0.04090	-3.514**
Condition x Group	-0.38321	0.04090	-9.369**
Type x Group	-0.07861	0.04090	-1.922
Condition x Type x Group	0.17818	0.05785	3.080**

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

3.2.4 Late Frontal Positivity (500-800 ms)

The late interval, from 520 to 679 ms, in the frontal model was analyzed with Group, Condition and Type as factors. The mixed model analysis revealed a main effect of Condition, where Different trials were generally more positive than Same trials regardless of language group. However, the best model included an interaction of Group x Type x Condition (see Table 6 for model results). Specifically, the ML group showed increased positivity for Difference trials, regardless of cognate status, but the BL group showed this pattern only for the cognate trials. (see Fig. 2).

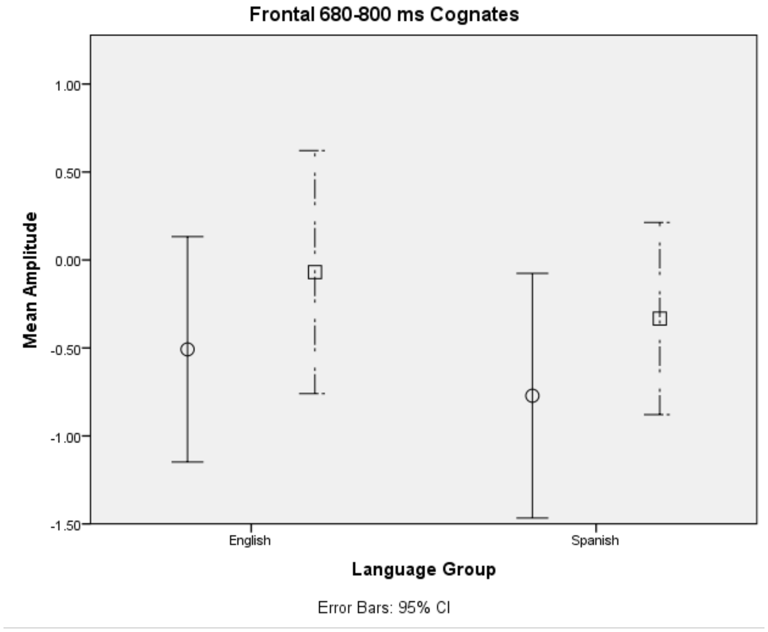
The time frame from 680-800 ms, showed a similar pattern to the prior interval, with a main effect of Condition reflecting greater positivity in response to the Different trials (see Table 6). The significant three-way interaction was the result of the monolingual participants showing the same pattern of increased positivity to the Different condition for cognate and non-cognate trials, but the bilingual participants showing this pattern only for cognate trials (see Fig. 3). To follow this up, an analysis examining word type separately revealed that Non-cognate trials showed a significant interaction of Group x Condition ($t = 4.8, p < 0.001$) whereas cognate trials did not ($t = .006, p = .9$).

In summary, in the late time intervals (after 500 ms) the two language groups showed similar neural discrimination responses for the cognate word pairs. In contrast, the BL group showed less robust neural discrimination for the non-cognate word types.

Table 6. Mixed model results for Frontal electrodes for the 520-679 ms and the 680-800 ms intervals. The intercept estimate is the ML Same non-cognate condition (in μVs).

Frontal 520-679 ms			
	Estimate	**Std. Error**	**t value**
(Intercept)	-0.14632	0.19331	-0.757
Condition	0.72108	0.02973	24.256*
Type	-0.01879	0.02973	-0.632
Group	0.03838	0.27338	0.140
Condition x Type	0.10136	0.04204	2.411
Condition x Group	-0.35577	0.04204	-8.462**
Type x Group	-0.41847	0.04204	-9.954**
Condition x Type x Group	0.24921	0.05946	4.191**
Frontal 680-800 ms			
	Estimate	**Std. Error**	**t value**
(Intercept)	-0.45426	0.26882	-1.690
Condition	0.36950	0.03662	10.090**
Type	-0.05372	0.03662	-1.467
Group	0.07349	0.38017	0.193
Condition x Type	0.06949	0.05179	1.342
Condition x Group	-0.37845	0.05179	-7.308**
Type x Group	0.33717	0.05179	-6.511**
Condition x Type x Group	0.37810	0.07324	5.162**

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



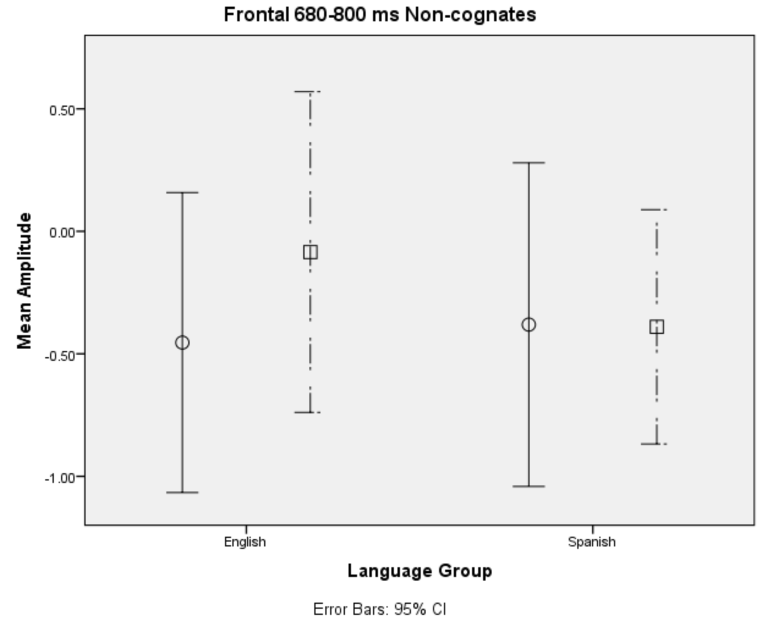


Fig. 3. Three-way interaction of group by condition by type for frontal model from 680-800 ms. cognates are shown in the top graph and Non-cognates in the bottom graph. Circles are mean amplitudes of Same trials, squares are mean amplitudes of Different trials. The amplitude to the Different trial is more positive than to the Same trial for all but the BL group for non-cognate word types.

3.2.5 Parietal Model

Figure 4 shows the Grand Mean ERP waveform at Parietal sites (Parietal model) for the cognates (top graph) and non-cognates (bottom graph) for each group and condition. Greater negativity of the Different condition (reflecting the N400) is observed from about 400 to 680 ms. This is followed by a late positivity to the Different condition. Mixed Effects Modeling was performed on successive intervals to determine the effect of Group, Type, and Condition on the ERP amplitude.

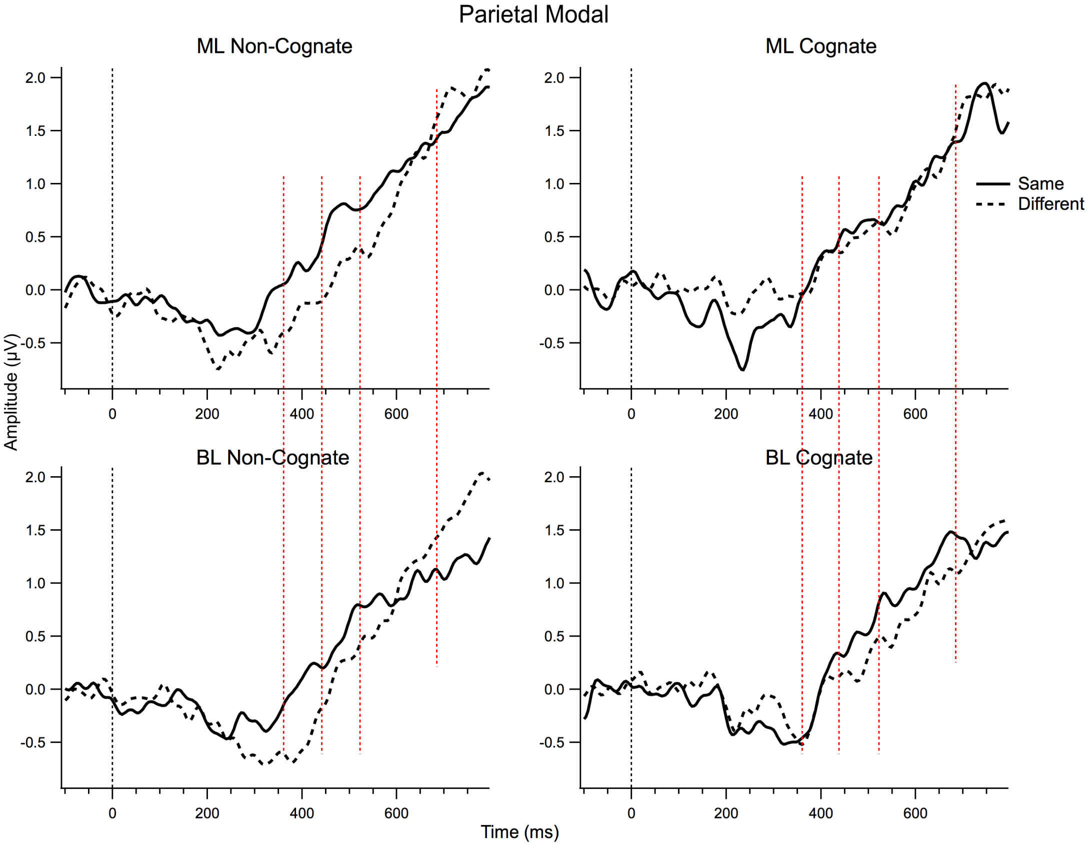


Figure 4. ML (top graphs) and BL (bottom graphs) Grand Mean ERPs to same and different trials for non-cognates (left graphs) and cognates (right graphs) in frontal model. The vertical red dashed lines show the time intervals used in the analyses.

3.2.5.1 200-359 ms intervals

The N400 response generally peaks 400 ms following word onset. However, the frontal model showed brain discrimination in an earlier 200-360 ms interval. Thus, to be able to evaluate the time course of processing the 200-360 ms interval was examined for the Parietal model. The mixed modeling showed that Condition, Group, and Type all significantly affected the response (see Table 7). The BL group had generally more negative responses to the Different condition than the ML group. The best fit model included a three-way interaction that was the result of both the ML and BL groups showing greater negativity of the Different compared to Same condition for the non-cognates, but the reverse pattern (greater positivity) for the cognates. In addition, the ML group showed a greater positive difference to cognates compared to the BL group.

In summary, this pattern indicated that an N400-like negativity began earlier for non-cognate than cognate trials for both groups and that there was a group difference for the cognate words.

Table 7. Mixed models results for parietal electrodes in the 200-359 ms time frame. The intercept estimate is the ML Same non-cognate condition (in µVs).

Parietal 200-359 ms			
	Estimate	**Std. Error**	**t value**
(Intercept)	-0.28233	0.12712	-2.221
Condition	-0.27198	0.03679	-7.392**
Type	-0.09250	0.03679	-2.514
Group	-0.05889	0.17978	-0.328
Condition x Type	0.57818	0.05203	11.112**
Condition x Group	0.10101	0.05203	1.941
Type x Group	0.03506	0.05203	0.674
Condition x Type x Group	-0.24007	0.07359	-3.262**

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

3.2.5.2 360-679 ms interval (N400)

Table 8. Mixed models results for parietal electrodes in the 360-439 ms, 440-519 ms and 520-679 ms time frames. The intercept estimate is the ML Same non-cognate condition (in µVs).

Parietal 360-439 ms			
	Estimate	**Std. Error**	**t value**
(Intercept)	0.19983	0.22020	0.907
Condition	-0.41506	0.04995	-8.310**
Type	0.07014	0.04995	1.404
Group	-0.13796	0.31141	-0.443
Condition x Type	0.34082	0.07063	4.825**
Condition x Group	-0.16686	0.07063	-2.362
Type x Group	-0.18419	0.07063	-2.608
Condition x Type x Group	0.19103	0.09989	1.912
Parietal 440-519 ms			
	Estimate	**Std. Error**	**t value**
(Intercept)	0.71530	0.24906	2.872
Condition	-0.54304	0.04972	-10.922**
Type	-0.06966	0.04972	-1.401
Group	-0.26577	0.35223	-0.755

Condition x Type	0.39299	0.07031	5.589**
Condition x Group	0.25524	0.07031	3.630**
Type x Group	0.12422	0.07031	1.767
Condition x Type x Group	-0.37010	0.09944	-3.722**
Parietal 520-679 ms			
	Estimate	**Std. Error**	**t value**
(Intercept)	1.10066	0.27565	3.993
Condition	-0.24161	0.03850	-6.276**
Type	-0.09546	0.03850	-2.480
Group	-0.22534	0.38983	-0.578
Condition x Type	0.14713	0.05445	2.702*
Condition x Group	0.25885	0.05445	4.754**
Type x Group	0.29717	0.05445	5.458**
Condition x Type x Group	-0.45791	0.07700	-5.947

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

To test whether the groups showed differences in amplitude modulation in the time frame and at electrode sites where N400 is expected, three intervals were examined for the Parietal model: 360-439 ms, 440-519 ms, and 520-679 ms. The two intervals from 520-599 and 600-679 ms were collapsed because they were highly correlated (r>.8). All three intervals showed a main effect of condition with more negative amplitudes to Different trials compared to Same trials. In the earlier 360-439 ms time frame, there was an interaction of Condition x Type; only the non-cognate condition showed increased negativity of the Different compared to Same conditions. The 440-519 ms and the 520-679 ms intervals revealed significant interactions of Condition x Type, Condition x Group, and Condition x Type x Group (see Table 8). The Condition x Type interactions were the result of the non-cognate trials showing greater negativity of the Different compared to Same trials, with less of a difference observed for cognate trials. The three-way interaction was the result of the BL group showing a more similar pattern for non-cognate and cognate trials (i.e., more negative Different than Same condition), whereas the ML group showed a smaller difference between conditions for the cognates (see Fig. 5, below, and Fig 4, above).

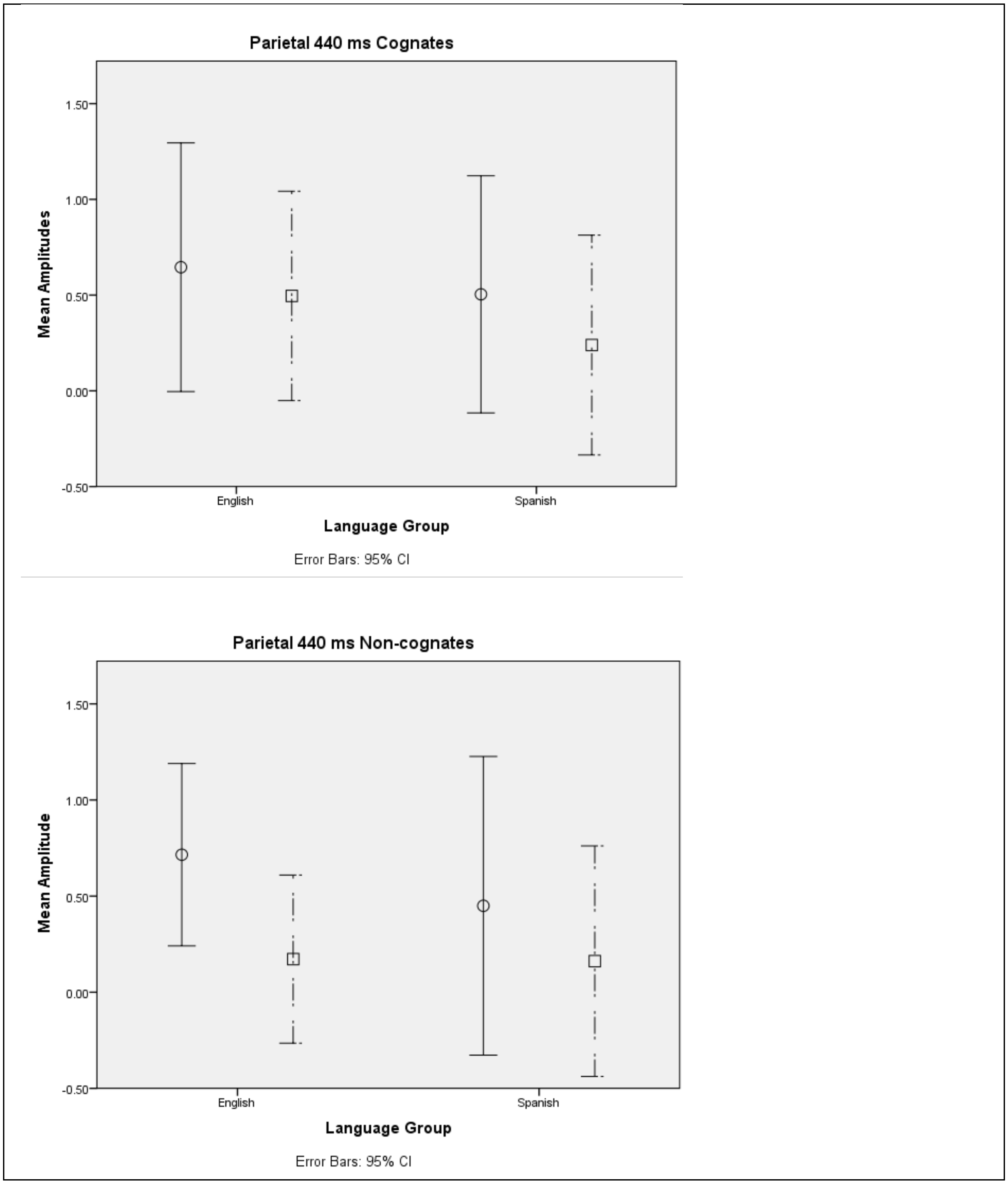


Fig. 5. Parietal site mean amplitudes (in µV) in the 440-519 ms time frame to cognate words (top graph), and to non-cognate words (bottom graph). Circles on solid lines are Same trials, squares on broken lines are Different trials.

In summary, greater negativity of the ERP to the Different condition was found from 360 ms to 679 ms, but this negativity was modulated by both Group and Type. Both groups showed a greater difference between the Same and Different conditions for the non-cognate than the cognate trials. In addition, from 440 to 679 ms the BL group showed a larger difference between conditions than the ML for the cognates.

3.2.6 Late Parietal Positivity (Late Positive Component or LPC)

The late time interval beginning 680 ms after word onset was examined to determine whether the apparent increased positivity for the different condition was significant. The 680-759 ms and 760-800 ms time frames were highly correlated ($r > .8$) and were collapsed for the analysis. The best model revealed a significant main effect of Condition (Different trials more positive than Same trials), a significant two-way interaction of Condition x Group and a three-way interaction of Condition x Type x Group (see Table 9). The interactions indicated that the BL group showed a greater difference between the Different and Same conditions, and this difference was larger for the non-cognate than cognate condition (see Fig 6). The increased difference was observed as greater positivity of the Different than the Same conditions.

Table 9. Mixed model results for parietal electrodes from 520-800 ms post-stimulus. The intercept estimate is the ML Same Noncognate condition.

Parietal 680-800 ms			
	Estimate Std.	**Error**	**t value**
(Intercept)	1.67283	0.29794	5.615
Condition	0.18879	0.04338	4.352**
Type	-0.02092	0.04338	-0.482
Group	-0.61674	0.42881	-1.438
Condition x Type	-0.04128	0.06135	-0.673
Condition x Group	0.18411	0.06244	2.949*
Type x Group	0.27412	0.06244	4.390**
Condition x Type x Group	-0.39711	0.08830	-4.497**

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

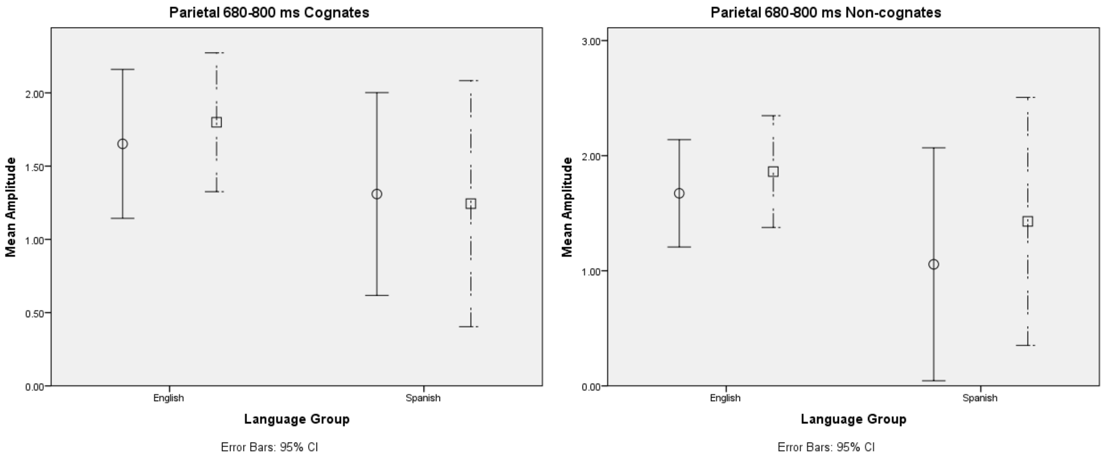


Fig. 6. Three-was interaction of group by condition by type for parietal model from 680-800 ms. The top graph shows cognate words, and the bottom graph shows non-cognate words. Circles on solid lines are mean amplitudes of Same trials, squares on broken lines are mean amplitudes of Different trials.

4. Discussion

The goal of this study was to determine whether the cognate status of words influenced L2 learners' phonological processing skills in their L2. Both the behavioral and brain measures showed that the bilingual and monolingual groups could discriminate the mispronunciations, but the bilingual group was less accurate at discriminating them. In addition, some group differences were observed in ERPs that suggested poorer discrimination. Specifically, for the Frontal model, the monolinguals showed earlier evidence of discrimination (200-360 ms) and a larger discriminative positivity in later time intervals (360-800 ms) compared to the bilinguals.

Cognate status did not affect behavioral discrimination, but it did modulate brain responses. For the Frontal model, the monolingual group showed a larger discriminative response for the non-cognates than the cognate trials from 360 to 800 ms. In contrast, the bilingual group had a larger discriminative response for the cognate than the non-cognate trials in the later time interval (520-800 ms). The Parietal model also showed effects of cognate status, but with an unexpected pattern. Specifically, both the bilingual and monolingual groups showed a larger negative discriminative effect (i.e., N400) to the non-cognate compared to cognate trials. This N400-like response began earlier for non-cognate than cognate trials. In fact, for the cognate trials, the ERP response to the different condition was more positive than the same condition in the early time interval that preceded the N400. The bilingual group showed less difference between cognate types for the later time intervals (450-780 ms). In addition, both groups showed a greater late positive discriminative response (LPC) to the non-cognate than cognate word types, and this difference was greater for the bilingual than the monolingual group. Below we interpret the pattern of results more fully in relation to our hypotheses and the previous literature.

4.1 ERP components and cognate status

4.1.1 Early Frontal Positivity

The frontal model showed an early emerging positive discriminative response from 200 to 360 ms that is likely to reflect phonetic and phonological processes of discrimination. This frontal topography is consistent with sources in the auditory cortex (Wagner, et al., 2012). The neural sources from the superior temporal plane of the auditory cortex are oriented such that the largest obligatory response is observed at fronto-central sites. The finding of an increased positivity to the stimulus change may reflect recovery-from-refractoriness. Specifically, repetition of the same stimulus leads to attenuation of the neural response (e.g., Wagner, et al., 2012). In the case of a different phoneme, a different neural population is involved, which was not attenuated by repetition. The bilingual participants did not show a difference between the Same and Different trials in the early time frame (around 200 ms), indicating that they are processing the phonetic information as belonging to the same phonemic category as the first stimulus in the stimulus pair (and thus, there is no recovery in amplitude). The group difference reveals that this positivity reflects phonological rather than acoustic-phonetic processing.

Most previous studies requiring judgments of a second word in a stimulus pair have not observed an increased positivity to the Different stimulus. Both stimulus and task differences may underlie different patterns of findings. The studies by Praamstra and colleagues (Praamstra & Stegeman, 1993; Praamstra, et al., 1994) have generally observed increased negativity (N400) to increased word difference; however, these studies compared a fully different word form to one that was less different (rhyming or alliterating). We will return to these studies below, when we discuss the N400 effect.

The increased positivity in the current paradigm might reflect similar processes to the P3a orienting response elicited in oddball paradigms. Many studies have shown that language experience affects discrimination of speech sounds 100 to 300 ms following a speech sound change using the mismatch negativity (MMN) response, which is elicited in an oddball paradigm (Näätänan, et al., 2007; Shafer, et al., 2015). MMN is typically elicited in a paradigm where the participant is asked to ignore the auditory stimuli and attend to the visual modality (usually by watching a muted video). A positive response, called the P3a, sometimes follows the MMN (between 200 and 400 ms), if the sound change is great enough to draw attention. The positivity in our study exhibited consistent topography and timing to reflect this P3a orienting processing (Polich, 2003).

Another possible explanation for this positivity is that it reflects the same processes as the P3b response, which is elicited in oddball paradigms in which participants are asked to respond to an infrequent deviant (e.g., Hisagi, et al., 2010; 2015). P3b typically has a posterior topography (largest over parietal sites) and occurs 300 to 600 ms following change detection. However, even though the current paradigm required attention to the stimulus pairs, the task in the current study was considerably different from these other studies. Participants were asked to determine whether each stimulus pair was the same or different and to respond to every stimulus pair. This, along with the very early timing (around 200 ms) and the frontal topography, may be better explained as a P3a response.

An alternative explanation is that this positivity reflects the same underlying processes as the phonological mismatch negativity (PMN) observed by Connolly and Phillips (1994). This PMN was observed in a similar time frame (around 200-400 ms), but was seen as an increase in negativity rather than positivity. In addition, their paradigm presented auditory sentences in which a phonologically unexpected word was presented.

This early time interval did not show an effect of cognate status. This absence of an effect is consistent with the suggestion that discrimination by the neural sources underlying the frontal model in this early time frame is based entirely on acoustic-phonetic and phonological properties.

4.1.2 P400 and Late Frontal Positivity

The P400 positivity extended from 360 to 800 ms and indicated discrimination by both monolingual and bilingual groups. However, the increased positivity was considerably larger for the monolingual than the bilingual group. In addition, the monolingual group showed a larger positivity to the non-cognate than cognate trials. In the later time intervals (520-800), the bilingual group showed a much larger difference for the cognate than the non-cognate trials. The generally larger responses for American-English participants suggest easier discrimination. In addition, these monolingual listeners appeared to find discrimination of the non-cognate trials easier than the cognate trials, as they showed a greater discriminative response to the non-cognate than cognate trials.

The only study using a similar design that has shown an increase in positivity approximately 400 ms following the stimulus difference is Wagner, et al. (2012). The similar design for the two studies suggest that this positivity reflects the same processes as the P400 in Wagner, et al. (2012). Other studies have observed increased negativity to stimulus difference between pairs (e.g., Praamstra, et al., 1994; 1995). Design difference may affect whether a positivity or negativity is observed. The studies exhibiting increased positivity compared the ERP responses to a word differing from a prime by one phoneme versus a word that was the same phonological form as the prime. The studies showing increased negativity of the ERP compared a word differing fully from the prime, to a word that differed partially from the prime. We will return to a discussion of these patterns in relation to the N400 below.

The pattern of results for the bilingual listeners suggests that the presence of a cognate in Spanish was actually helpful, because the bilingual listeners showed a greater discriminative response to the cognate than non-cognate trials. More specifically, the bilingual listeners P400 response was more similar in amplitude to the monolingual controls for the cognate than non-cognate trials. Keep in mind that the very large P400 to the non-cognate trials suggests that the words in this condition were the easiest to discriminate for the monolinguals.

This finding may indicate that the cognate status of the lexical item allows for a more accurate L2 phonological representation, and this increased precision facilitates L2 vowel discrimination. Wagner et al. (2012) proposed that the P400 is sensitive to both acoustic and linguistic information. Specifically, the P400 difference was observed in an earlier time interval for the native language group (Polish) compared to the non-native listeners (English) to at *pt*-onset versu *p*-schwa-*t* onset (e.g., *ptola* versus *petola*). The current findings are consistent with this pattern in that the monolingual L1 group show an earlier and larger effect that the bilingual group, who are late learners of American English.

The relatively late onset of the P400 (compared to a discriminative component such as MMN) suggests that it may be an index of conscious discrimination of speech sounds (Wagner et al., 2012). It is also possible that the P400 is related to the P3a orienting response, discussed in the previous section. Topographical analysis will be needed using a design that directly compares P3a and P400 to the same stimulus in the same participants to determine whether the two components might have the same neural generators. It is unclear whether lexical access, as indexed by N400, directly influences this response, but the current results and analysis cannot address the relationship between the P400 and N400. However, the P400 can be elicited using nonsense word stimuli, as in the study by Wagner, et al. (2012), indicating that lexical access is not necessary. This will be discussed further, below.

4.1.3 Parietal Model N400

Based on past research, we anticipated that the language-based differences might be reflected in N400 modulation. The N400 component can serve as an indication that a semantic and/or phonological mismatch has been detected (Holcomb & Neville, 1990; Praamstra et al., 1994). In the current study the N400 component reflected lexical access, but did not clearly indicate language-specific effects. Both groups demonstrated a larger negativity at posterior sites to Different compared to Same trials, but both groups also showed a larger effect for the non-cognate than cognate words. However, this does not necessarily suggest that the two groups perceived these vowel contrasts in the same manner. Given the behavioral results that demonstrated a significant difference in accuracy responses, BLs are not perceiving the changes in vowels as well as MLs.

The topography and latency of this negativity is consistent with the N400. Thus, we can conclude that identical priming (that is, repetition of the same form) more fully primed the second word in a pair than a prime in which one vowel differed from the second word. Studies that have used repetition of words (that are presented in lists) have shown a reduction in negativity at the latency where N400 is expected (Rugg, 1990). These repetition-priming study designs are generally used to examine memory for previously encountered information, but the pattern of findings is consistent with an explanation that priming with the full phonological form allows for easier access to the lexical representation on a subsequent repetition of the form.

The finding of a larger N400 effect for non-cognate compared to cognates for the monolinguals suggests that the two sets of words may have differed in some other factor than cognate status (which should only be relevant to the bilingual listeners). These two sets of words were necessarily different, making it difficult to control for all factors that might influence lexical access. We attempted to control for other factors, but it was necessary to find a sufficient number of stimulus pairs with the three target English vowels and in which the vowel was found in stressed syllable position. In addition, the presence of a cognate word in Spanish constrained stimulus selection. Word frequencies between cognate and non-cognate stimuli did not differ significantly, but it was not possible to control for prevocalic consonant (i.e., all manner of consonants were used including stops, fricatives, and liquids). Differences in these other factors may have influenced the latency and the amplitude of the N400 response. Even so, we found a language group effect; with bilingual participants actually showing greater negativity than the monolinguals to the different trials for the cognate condition. This indicates that for cognate pairs, the phonetic difference was less effective than the identical form at priming the second word of a pair. In contrast, the monolingual group showed equal priming from for the identical and phonetically-different pairs.

Below, we will return to this finding when we discuss how cognate status affects lexical access.

4.1.4 LPC

In the current study, the predicted pattern of a greater positivity to the different trials was evident for non-cognates trials in the bilingual group. This positivity may reflect the same processes as the late positive component (LPC) observed in other studies (e.g., Wagner, et al. 2012). We propose that the LPC indexes their effort in responding during the discrimination task. The bilingual group showed a larger LPC than the monolingual group, especially for the non-cognates, which is consistent with the interpretation of the LPC reflecting effort. In this case, our findings suggest that the presence of phonologically similar translation equivalents in the L1 facilitated discrimination. The alternative interpretation is the LPC indexes ease of discrimination. This latter interpretation, however, is at odds with the finding from the frontal model, in which a larger discriminative response was found for cognates. As noted above, however, the behavioral responses were not different for cognate and non-cognate trials.

The LPC has been shown to reflect differences in speech discrimination based on native language experience (Wagner et al., 2012). However, in the Wagner et al. study, only native listeners (Polish) showed an LPC to the phonological contrasts (/pt/ onset cluster that is allowed in Polish but not English). In addition, only the Polish group was able to behaviorally categorize the stimulus types (/pt/ versus p-schwa-t). A study that examined non-native speech discrimination, with a somewhat similar design to ours, revealed that a greater phonological difference between the prime and target word resulted in a larger LPC (Dehaene-Lambertz et. al, 2000). Thus, these studies suggest that interpretation of LPC amplitude differences needs to be considered in relationship to the behavioral responses.

A study by Verleger and colleagues (2005) indicated that the LPC can be modulated by response selection (Verleger, Jaskowski, & Wascher, 2005). In the current study, it seems that the LPC reflected extra effort required to access a less familiar lexical entry. Given that the participants in the current study were asked to make a discrimination judgment, the LPC appears to reflect the difficulty in detecting the stimulus difference, with non-cognates requiring greater effort. Thus, it seems that the cognate status may have facilitated discrimination, perhaps by allowing the listener to notice the difference. However, this effect did not lead to better behavioral discrimination.

4.2 Cognates and their effect on lexical access

The ERP results suggest that cognate status has an effect on phonological perception. A person's ability to modulate phonological routines that will be applied to an L2 appears to be better when an L2 word shares a cognate equivalent in their L1. More specifically, the neural activity reflecting phonological discrimination (measured in the frontal model) indicated that bilingual listeners were able to enhance L2 discrimination at the neural level using lexical knowledge (i.e., that the L2 word had an L1 cognate). Even so, this enhanced brain discriminative response did not translate into better behavioral discrimination of cognate than non-cognate trials. This absence of a behavioral difference may indicate that the behavioral task was not sensitive enough to pick up this difference.

Previous studies have indicated that lexical selection in bilinguals is not language-specific and access to cognate equivalents is facilitated perhaps because cognates are at a lower threshold for activation (Colome, 2001; Costa, Miozzo, & Caramazza, 1999). A greater number of competitor lexical items (coming from both languages) may be activated for cognates than for non-cognates and, thus, contribute to a bilingual's selection of a phonological form corresponding to the lexical item in the non-target language. In the current study, correctly-pronounced and mispronounced cognate forms both seemed to facilitate lexical access to the English word, in that the N400 measure showed little difference between same and different pairs. In contrast, the correctly-produced versus mispronounced non-cognate forms were less effective in priming each other, resulting in a more negative ERP response over parietal sites to the different compared to same trials.

It is important to consider that the discrimination task used in this study did not require participants to access the lexicon. The finding of an increased negativity, however, suggests that participants were accessing lexical entries. Two studies using a somewhat similar paradigm to the current study indicated that lexical access is somewhat automatic and thus N400 can be elicited in a phonological discrimination or rhyming task (Praamstra & Stegeman, 1993; Praamstra, Meyer & Levelt, 1994).

As suggested by Strijkers, Costa, and Thierry (2009), a cognate word may provide lexical processing advantages similar to those of word frequency effects. For non-cognate words, bilinguals showed poorer and later phonological discrimination (at frontal sites), resulting in incorrectly identifying 26% of the different pairs as same. However, it seems that they still showed greater priming for Same pairs than for Different pairs for these non-cognates, according to the parietal N400, indicating that the mispronunciations were not accepted as good exemplars of the intended lexical entry.

According to Green's (1998) inhibitory control model, bilinguals should be able to inhibit L1 lexical selections when the target words are in their L2; however, the phonological changes presented in the current study may have caused cross-language interference based on L1 perceptual routines being activated. According to the cascading view of lexical access by Dell (1986) and Dell, Schwartz, Martin, Saffran, and Gagnon, (1997), spreading of activation across a bilingual's lexical entries with similar phonological properties will occur. Thus, all lexical entries across the languages sharing phonological properties will be activated. Clearly, activation of the L2 lexical entry was triggered by both the correct, and mispronounced forms for cognates.

4.3 L2 proficiency

Our behavioral results indicated that although our bilinguals were all conversationally proficient, bilinguals were less accurate than monolinguals in perceiving the vowels changes. The participants in the bilingual group who demonstrated the most difficulty with this task did not show poor performance on the 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 out of the group of conversationally proficient bilinguals. Proficiency levels, as measured by comprehension and discourse fluency, are likely somewhat independent of speech perception skills.

Past studies have demonstrated poor discrimination of L2 phonological contrasts even in early bilinguals (Sebastian-Galles et al., 2006); it is possible that the lexical support from real words in our study led to more accurate discrimination by the bilinguals than would not be found in a task using non-words. With regard to differential response to word Type, past studies have shown that cognates are facilitative regardless of L2 proficiency level (Christoffels, De Groot, & Kroll, 2006). The findings from the current study are consistent with these prior observations in that bilinguals showed more accurate neural discrimination of mispronunciations of cognates than non-cognates.

4.4 L2 vowel perception

If bilinguals used their L1 SPRs (Strange, 2006/2011) to perceive L2 sounds, then inaccurate categorization of new L2 vowel contrasts would be expected; however, both PAM-L2 (extension of PAM, Best & Tyler, 2007; Best, 1995) and the SLM (Flege, 1992) posit that experienced bilinguals can begin to form new vowel categories. In the current study, reliance on Spanish L1 SPRs would result in the mispronounced counterpart of each of the three-English target vowels being assimilated into one phoneme category (e.g., /ɪ/ assimilated into /i/), rather than two categories as expected for English listeners (Fox, Flege, & Munro, 1995; MacDonald, 1989). Confusion of minimal pair words containing L2 phonemes that have been assimilated into one L1 category has been demonstrated even in early bilingual populations (Sebastian-Galles et. al, 2006.) Our behavioral results revealed that Spanish-English bilinguals could discriminate these English vowel contrasts (although not as well as monolinguals). Our electrophysiological results indicate that vowel discrimination is more robust for cognate words, suggesting that lexical connections are linked to improved phonological processing in bilinguals. The neural measures shed additional light on this process by indicating that this enhanced discrimination is reflected at a fairly late stage that is likely to require attention (440 ms and later). Future studies will be necessary to determine whether cognate word facilitation is seen at an earlier attention-independent level. For example, an MMN oddball design (e.g., Hisagi et al., 2014) could be used to see whether automatic discrimination of these vowels in cognate words would be more robust than for non-cognate words.

The mispronunciations of the stressed vowels in the current study were meant to simulate bilinguals' perception of native English speakers, although no effort was made to have these vowels specifically mimic Spanish formant frequencies. In many instances, a change of one phoneme can affect the meaning of the word and lead to confusion on the part of the L2 listener (e.g., *battle* vs. *bottle*). In the current study, results from ERPs recorded at frontal sites indicated that accurate speech discrimination is modulated by cognate status; thus, L2 words that are more closely related to words in the L1 will be processed more accurately.

Bilinguals were significantly less accurate at identifying Different pairs than they were at identifying Same pairs. It is also possible that some of the participants judged changes made to the vowels as either good or bad exemplars, and not two different vowel categories, as they were asked whether the words were pronounced the same or differently and not whether they were pronounced "accurately."

4.5 Limitations and future directions

Limitations of the current study included a somewhat homogenous group of bilinguals. Thus, we could not examine how proficiency affected the response. We also had considerable variability in word frequency. A more homogeneous set of words with regards to frequency would help explain the cognate/non-cognate difference found for monolingual participants. In addition, the bilingual participants might experience different frequencies for these items, and thus it would be useful to have familiarity ratings from these participants. Another limitation of the current study was that the words were produced with an "accent" on only one phoneme, whereas Spanish speakers typically accent the entire word. This led to somewhat artificial word pronunciations, but it is important to note that most ERP studies of L2 speech processing have used synthesized, isolated phonemes or CV syllables. Thus, compared to previous studies, these findings are likely to better reflect real-world lexical processing.

Our monolingual participants may have had some experience with Spanish-accented English leading to tolerance of many of the mispronounced cognate words as variants of the target. A future study using a lexical decision task could clarify whether monolinguals show faster access to the lexical entries for cognate than non-cognate productions, and to what extent reaction time is influenced by familiarity with the accent. It would also be worthwhile to conduct a study in which accent modification treatment is completed at the word level and cognates versus non-cognates are compared in overall improvement over time.

4.6. Theoretical implications

This study provided novel information on the processes underlying lexical access in monolingual and bilingual listeners. Lexical access is often viewed as a linear process flowing from acoustic-phonetic encoding to phonological/speech perception to lexical access. The current findings suggest a more interactive account (e.g., Dell, 1986). The phonological processing appears to slightly precede lexical access based on the finding that the monolinguals showed more accurate discrimination than the bilinguals in the frontal model from about 200-360 ms, and because there was no effect of lexical status. However, by 360-440 ms, effects of cognate status were found for both the frontal model and the parietal model. If, as we hypothesized, the frontal model reflects processing in the auditory cortex, this suggests that lexical access (as indexed by the parietal model) influences phonological discrimination in this later time frame. It would follow that, lexical access influences phonological processing, rather than phonological processing being complete before the onset of lexical access processes.

5. Conclusions

The current study extended our knowledge of how phonological processing in an L2 is impacted by the cognate status of the words in that language. The study revealed that bilinguals generally have more difficulty processing and perceiving L2 words than monolingual L1 listeners, but that phonological processing in the L2 is facilitated for cognate compared to non-cognate words. The neural measures demonstrated that cognate status impacts phonological and lexical processing differently. Cognate status can improve phonological discrimination at the neural level, but does not necessarily affect lexical access of correctly produced versus mispronounced forms, as indexed by the N400. Our findings also suggest that cognate status does not only facilitate vocabulary learning, but may also facilitate L2 speech perception learning in adult learners. Future studies will be needed to more closely examine the interaction between lexical and phonological factors during the process of second language learning.

Acknowledgments

The authors would like to thank Yan Yu, Hia Datta, Monica Wagner, and Luca Campanelli.

Appendix A

Table A1
Descriptive information for all bilingual participants. Grammar test score is out of a possible 15 correct. TVIP column represents a standard score; this test reports a mean of 100 and standard deviation of 15. Percent accuracy is accuracy achieved during discrimination experiment (answers to same/different task). LOR represents length of residence in the USA. PPVT results are the number incorrect on numbers 73-144 (a total of 71 items presented) of the test.

Participant	Age	Gender	AOA	LOR (years)	Birth Place	TVIP	PPVT	Grammar Test	%Accuracy
1	26	m	16	10	Mexico	109	9	11	83%
2	42	f	31	11	Mexico	121	9	10	75%
3	25	m	25	0.25	Colombia	119	20	9	71%
4	34	m	22	12	Dom. Rep.	119	7	15	85%
5	39	m	36	3	Colombia	123	9	12	85%
6	27	f	21	6	Mexico	120	6	12	89%
7	33	f	25	8	Peru	115	6	13	90%
8	35	f	28	7	Mexico	118	7	12	70%
9	33	m	17	16	Colombia	120	7	13	93%
10	32	f	21	11	Colombia	119	8	14	84%
11	42	f	18	24	Peru	115	10	9	57%
12	31	m	14	17	Colombia	117	8	9	91%
13	31	m	18	13	Spain	121	13	15	85%
14	33	f	16	17	Prto. Rico	105	9	10	81%
15	37	m	23	14	Colombia	111	21	8	89%

Appendix B

Table A2: List of word stimuli along with their Spanish translations. It should be noted that in many cases the words have a similar cognate, however they may also have translation equivalents that are not cognates (e.g., fragment is a direct translation of 'fragmento', however the words *parte* or *trozo* in Spanish could also be used.) Word frequencies based on 51 million words. The vowel that was changed has been underlined.

Non-Cog Word	Translation	Frequency	Cog Word	Translation	Frequency
begin	comenzar	2906	abyss	abismo	90
bracket	soporte	32	arrest	arresto/arrestar	3037
candle	vela	409	attack	ataque/atacar	3853
candy	dulce/caramelo	1825	battle	batalla	2155
canvas	lienzo	216	cancel	cancelar	933
children	niños	8930	commence	comenzar	235
depict	representar	27	confess	confesar	808
dinner	cena	10336	cynic	cínico	56
dismiss	despedir	279	demand	demanda/demandar	873
dizzy	mareado	430	detect	detectar	261
fender	parachoques	130	differ	diferir	124
flatter	halagar/adular	200	direct	directo/dirigir	1226
forbid	prohibir	436	event	evento	1345
forget	olvidar	14130	exact	exacto	1154
forgive	perdonar	3917	figure	figura	6598
gamble	jugar	456	fragment	fragmento	96
gentle	suave	844	infect	infectar	62
giggle	reir/risilla	87	magic	magia	2687
happen	suceder/ocurrir	12968	mandate	mandato	76
headlight	faro	37	manner	manera	588
healthy	saludable	1262	passport	pasaporte	534
heaven	cielo	2887	rebel	rebelde	273
matter	importar/materia	18900	racket	raqueta	379
magnet	imán	140	second	segundo	14513
parrot	loro/cotorra	167	system	sistema	4667
rattle	sonajero	172	talent	talento	1332
ready	listo/preparado	19778	timid	tímido	77
regret	lamentar	1384	victim	víctima	2434
sister	hermana	9207			
tickle	cosquillas	245			
until	hasta	15426			
village	pueblo	1712			
willful	voluntarioso	35			

References

Amengual, M. (2012). Interlingual influence in bilingual speech: Cognate status effect in a continuum of bilingualism. *Bilingualism: Language and Cognition*, *15*(3), 517-530.

Baker, W., & Trofimovich, P. (2005). Interaction of native- and second-language vowel system(s) in early and late bilinguals. *Language and Speech, 48*, 1-27.\

Barrios, S., Jiang, N., & Idsardi, W. J. (2016). Similarity in L2 Phonology: Evidence from L1 Spanish late-learners' perception and lexical representation of English vowel contrasts. *Second Language Research*, *32*(3), 367-395.

Bates D., Maechler M., Bolker B., & Walker S. (2013). Fitting Linear Mixed-Effects Models Using lme4. R package version 1.1-13.

Best, C. T., and Tyler, M. D. (2007). "Nonnative and second-language speech perception: Commonalities and complementarities," in *Language Experience in Second Language Speech Learning: In Honor of James Emil Flege*, edited by O. -S. Bohn and M. J. Munro (John Benjamins, Amsterdam), pp. 13-34.

Bohn, O. S., Best, C. T., Avesani, C., & Vayra, M. (2011). Perceiving through the lens of native phonetics: Italian and Danish listeners' perception of English consonant contrasts. In *International Congress of Phonetic Sciences* (Vol. 17, pp. 336-339).

Bradlow, A. R. (1995). A comparative acoustic study of English and Spanish vowels. *The Journal of the Acoustical Society of America*, *97*(3), 1916-1924.

Brysbaert , M. New , B. (2009). Moving beyond Kučera and Francis: A critical evaluation of current word frequency norms and the introduction of a new and improved word frequency measure for American English. Behavior Research Methods, 41, 977-990

Casillas, J. V., & Simonet, M. (2016). Production and perception of the English/æ/–

/ɑ/contrast in switched-dominance speakers. *Second Language Research*, *32*(2),

171-195.

Christofells, I. K., De Groot, A. M. B., & Kroll, J. F. (2006). Memory and language skills in simultaneous interpreters: the role of expertise and language proficiency. *Journal of Memory and Language*, 54, 324-345.

Colomé, A. (2001). Lexical activation in bilinguals' speech production: Language specific or language-independent? *Journal of Memory and Language, 45*(4), 721-736.

Connolly, J. F. & Phillips, N. A. (1994). Event-related potential components reflect phonological and semantic processing of the terminal word of spoken sentences. *Journal of Cognitive Neuroscience*, 6, 256-266.

Costa, A., Caramazza, A., & Sebastián-Gallés, N. (2000). The cognate facilitation effect: Implication for models of lexical access. *Journal of Experimental Psychology, 26* (5), 1283-1296.

Costa, A., Miozzo, M., & Caramazza, A. (1999). Lexical selection in bilinguals: Do words in the bilingual's two lexicons compete for selection? *Journal of Memory and Language, 41*, 365–397

Costa, A., Santesteban, M., & Caño, A. (2005). On the facilitatory effects of cognate words in bilingual speech production. *Brain and language*, *94*(1), 94-103.

D'Arcy, R.C.N., Connolly, J.F., & Crocker, S.F. (2000). Latency shifts in the N2b component track phonological deviations in spoken words. *Clinical Neurophysiology, 111*(1), 40-44.

de Bleser, R., Dupont, P, Postler, J, Bormans, G., Speelman, D., Mortelmans, L., & Debrock, M. (2003). The organization of the bilingual lexicon: A PET study. *Journal of Neurolinguistics, 16*, 439-456.

de Groot, A. M. D. & Nas, G. L. J. (1991). Lexical representation of cognates and noncognates in compound bilinguals. *Journal of Memory and Language*, *30*, 90-123.

Dehaene-Lambertz G, Dupoux E, Gout A. (2000). Electrophysiological Correlates of Phonological Processing: A Cross-linguistic Study. *Journal of Cognitive Neuroscience, 12*(4):635-647.

Dell, G. S. (1986). A spreading activation theory of retrieval in language production. *Psychological Review, 93*, 283–321

Dell, G. S., Schwartz, M. F., Martin, N. M., Saffran, E. M., & Gagnon, D. A. (1997). Lexical access in aphasic and nonaphasic speakers. *Psychological Review*, *104*, 801-838.

Derwing, T.M. (2003). What do ESL students say about their accents? *Canadian Modern Language Review, 59,* 545-564.

Dijkstra, A., Grainger, J., & van Heuven, W. (1999). Recognition of cognates and interlingual homographs: The neglected role of phonology. *Journal of Memory and Language,* 42, 465-480.

Dijkstra, A., Miwa, K., Brummelhuis, B., Sappelli, M., & Baayen, H. (2010). How cross-language similarity and task demands affect cognate recognition. *Journal of Memory and Language*, 62, 284-301.

Dijkstra, T., & Van Heuven, W. J. B. (1998). The BIA-model and bilingual word recognition. In J.Grainger & A. Jacobs (Eds.), *Localist connectionist approaches to human cognition* (pp. 189-225). Mahwah, NJ: Lawrence Erlbaum Associates Inc.

Dunn, D. M., & Dunn, L. M. (2007). *Peabody Picture Vocabulary Test, Fourth Edition, manual*. Minneapolis, MN: NCS Pearson, Inc.

Dunn, L. M., Padilla, E. R., Lugo, D. E., & Dunn, L. M. (1986). *Test de Vocabulario en Imágenes Peabody (TVIP)*. Circle Pines, MN: AGS.

Flege, J. E. (1991). The interlingual identification of Spanish and English vowels: Orthographic evidence. *The Quarterly Journal of Experimental Psychology*, *43*(3), 701-731.

Flege, J. E. (1992). Speech learning in a second language. In *Phonological Development: Models, Research, Implications (pp. 233-277)*, C. Ferguson, L. Menn, & C. Stoel-Gammon (eds.), Timonium, MD: York Press.

Flege, J. E., Bohn, O.-S. & Jang, S., 1997, Effects of experience on non-native speakers' production and perception of English vowels. *Journal of Phonetics* 25(4), 437-470.

Flege, J.E. & Mackay, I.R.A. (2004). Perceiving vowels in a second language. *Studies in Second Language Acquisition, 36*, 1-34.

Flege, J., Mackay, I. R. A., & Meador, D. (1999). Native Italian speakers' production and perception of English vowels. *Journal of the Acoustical Society of America*, 106(5), 2973-2987.

Flege, J., Munro, M., & Fox, R. (1994). Auditory and categorical effects of cross-language vowel perception. *Journal of the Acoustical Society of America, 95(6)*, 3623-3641.

Flege, J., Munro, M. & MacKay, I. (1995) Factors affecting degree of perceived foreign accent in a second language, *Journal of the Acoustical Society of America*, *97(5)*, 3125-3134

Fox, R. A. (1984). Effect of lexical status on phonetic categorization. *Journal of Experimental Psychology: Human perception and performance*, *10*(4), 526.

Fox, R., Flege, J., & Munro, M. (1995). The perception of English and Spanish vowels by native English and Spanish listeners: A multidimensional scaling analysis. *Journal of the Acoustical Society of America*, *97(4)*, 2540-2551.

Gollan, T. H. & Acenas, L.A. (2004). What is a TOT? Cognate and translation effects on tip-of-the-tongue states in Spanish–English and Tagalog–English bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. 2004, 30(1), 246–269.

Green, D. W. (1998). Mental control of the bilingual lexico-semantic system. *Bilingualism: Language and cognition*, *1*(02), 67-81.

Hammond, R. H. (1986). Error analysis and the natural approach to teaching foreign languages. *Lenguas Modernas*, *13*, 129-139.

Hisagi, M., Garrido-Nag, K., Datta, H., & Shafer. V. L. (2014). ERP indices of vowel processing in Spanish-English bilinguals. *Bilingualism: Language and Cognition*, *firstview, 1*. **DOI:** 10.1017/S1366728914000170

Hillenbrand, J., Getty, L. A., Clark, M. J., & Wheeler, K. (1995). Acoustic characteristics of American English vowels. *Journal of the Acoustical Society of America*, *97*(5), 3099-3111.

Holcomb, P. J & Neville, H. J. (1990). Auditory and visual semantic priming in lexical decision: A comparison using event-related brain potentials. *Language and Cognitive Processes*, 5(4), 281-312.

Kutas, M., & Federmeier, K. D. (2011). Thirty years and counting: Finding meaning in the N400 component of the event related brain potential (ERP). *Annual review of psychology*, *62*, 621.

Levy, E. S. & Law II, F. F. (2010). Production of French vowels by American-English learners of French: Language experience, consonantal context, and the perception-production relationship. *Journal of the Acoustical Society of America, 128*(3), 1290-1305.

Levy, E. S. & Strange, W. (2008). Perception of French vowels by American English adults with and without French language experience. *Journal of Phonetics*, 36(1), 141-157.

Linden, D. E. J. (2005) The P300: Where in the brain is it produced and what does it tell us? *Neuroscientist. 11(6)*, 563-576.

MacDonald, M. (1989). "The influence of Spanish phonology on the English spoken by United States Hispanics", in Bjarkman, Peter; Hammond, Robert, *American Spanish pronunciation: Theoretical and applied perspectives*, Washington, D.C.: Georgetown University Press, pp. 215–236

Nip, I. S., & Blumenfeld, H. K. (2015). Proficiency and Linguistic Complexity Influence Speech Motor Control and Performance in Spanish Language Learners. *Journal of Speech, Language, and Hearing Research*, *58*(3), 653-668.

Oyama, S.C. (1976). A sensitive period for the acquisition of a phonological system. *Journal of Psycholinguistic Research,* 5, 261-283.

Pallier, C., Colomé, A., & Sebastián-Gallés, N. (2001). The influence of native language phonology on lexical access: Exemplar-based versus abstract lexical entries. *Psychological Science*, *12*(6), 445-449.

Peltola, M. S., Kujala, T., Tuomainen, J., Ek, M., Altonen, O., & Naatanen, R. (2003). Native and foreign vowel discrimination as indexed by the mismatch negativity (MMN) response. *Neuroscience Letters*, *352*(1), 25-28.

Pickering, E. & Schweinberger, S. R. (2003). N200, N250r, and N400 Event-related brain potentials reveal three loci of repetition priming in familiar names. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29*(6), 1298-1311.

Pisoni, D. B., & Tash, J. (1974). Reaction times to comparisons within and across phonetic categories. *Attention, Perception, & Psychophysics*, *15*(2), 285-290.

Polich, J. (2003). Overview of P3a and P3b. In J. Polich (Ed.), *Detection of change: Event-related potential and fMRI findings* (pp. 83-98). Boston, MA: Kluwer Academic Press.

Praamstra, P., Meyer, A. S., & Levelt, W. J. M. (1994). Neurophysiological manifestations of phonological processing: latency variations of a negative ERP component timelocked to phonological mismatch. *Journal of Cognitive Neuroscience*, *6*(3), 201-219.

Praamstra, P., & Stegeman, D. F. (1993). Phonological effects on the auditory N400 event-related brain potential. *Cognitive Brain Research*, *1*(2), 73-86.

R Core Team. R: A language and environment for statistical computing. R. Foundation for Statistical Computing, Vienna, Austria.

Rugg, M. D. (1990). Event-related brain potentials dissociate repetition effects of high- and low-frequency words. *Memory & Cognition*, *18*(4), 367-379.

Sánchez-Casas, R.M., Davis, C. W., & Garcia-Albea, J. E., (1992). Bilingual lexical processing: Exploring the cognate/non-cognate distinction. *European Journal of Cognitive Psychology*, *4*(4), 293-310.

Schoonbaert, S., Holcomb, P. L., Grainger, J., & Hartsuiker, R. J. (2011). Testing asymmetries in noncognate translation priming: Evidence from RTs and ERPs. *Psychophysiology, 48*(1), 74-81.

Sebastián-Gallés, N., Rodríguez-Fornells, A., de Diego-Balaguer, R., & Díaz, B. (2006 First and second language phonological representations in the mental lexicon. *Journal of Cognitive Neuroscience*, *18*(8), 1277-1291.

Sebastián-Gallés, N., & Soto-Faraco, S. (1999). Online processing of native and non-native phonemic contrasts in early bilinguals. *Cognition*, *72*: 111-123.

Shafer, V. L., Morr, M. L., Kreuzer, J., & Kurtzberg, D. (2000). Maturation of mismatch negativity in school-age children. *Ear and Hearing*, *21*(3), 242–251.

Shook, A., & Marian, V. (2013). The bilingual language interaction network for comprehension of speech. *Bilingualism: Language and Cognition*, *16*(2), 304-324.

Small, L. H. (2012). *Fundamentals of phonetics: A practical guide for students* (3rd ed.) Saddle River, NJ: Pearson Education, Inc.

Squires, N. K., Squires, K. C., & Hillyard, S. A. (1975). Two varieties of long-latency positive waves evoked by unpredictable auditory stimuli in man. *Electroencephalography and clinical neurophysiology*, *38*(4), 387-401.

Strange W. (2006). Second-language speech perception: The modification of automatic selective perceptual routines. *Journal of the Acoustical Society of America*, *120*, 3137.

Strange, W. (2007). Selective perception, perceptual modes, and automaticity in first- and second-language processing. *Journal of the Acoustical Society of America, 122*, 2970.

Strange, W. (2011). Automatic selective perception (ASP) of first and second language speech: A working model. *Journal of Phonetics*, *39* (4), 456-466.

Strange, W. Akahane-Yamada, R. Kubo,R. Trent, S. A., Nishi, K., & Jenkins, J. J. (1998). Perceptual assimilation of American English vowels by Japanese listeners, *Journal of Phonetics*, *26*(4), 311-344.

Strange, W., & Shafer, V. L. (2008). Speech perception in second language learners: The re-education of selective perception. In J. G. Hansen Edwards & M. L. Zampini, (Eds.) *Phonology and second language acquisition*, (pp. 153-191).

Strijkers, K., Costa, A., & Thierry, G. (2009). Tracking lexical access in speech production: electrophysiological correlates of word frequency and cognate effects. *Cerebral cortex*, bhp153.

U.S. Census Bureau. (2011). *The Hispanic Population: 2010. 2010 Census briefs: Allegany County, N.Y.* Retrieved October 10, 2014, from http://www.census.gov/prod/cen2010/briefs/c2010br-04.pdf.

Verleger, R., Jaskowski, P., & Wascher, E. (2005). Evidence for an in-tegrative role of P3b in linking reaction to perception. *Journal of Psychophysiology*, *19*(3), 165–181.

Wagner, M., Shafer, V. L., Martin, B., & Steinschneider, M. (2012). The phonotactic influence on the perception of a consonant cluster /pt/ by native English and native Polish listeners: A behavioral and event related potential (ERP) study. *Brain & Language*, *123*(1), 30-44.

Winkler, I., Kujala, T. Tiitinen, H., Sivonen, P., Alku, P., Lehtokoski, A., Czigler, I., Csepe, V., Ilmoniemi, R. J. & Näätänen, R. (1999). Brain responses reveal the learning of foreign language phonemes. *Psychophysiology*, *36*(5), 638-642.

Yu, Y. H., Shafer, V. L., & Sussman, E. S. (2017). Neurophysiological and Behavioral Responses of Mandarin Lexical Tone Processing. *Frontiers in Neuroscience*, *11*, 95.