CROSS-LANGUAGE NEIGHBORHOOD DENSITY EFFECTS IN EARLY AND LATE BILINGUAL WORD RECOGNITION

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ABSTRACT

A central debate in research involving bilinguals is related to how the languages possessed by bilinguals interact while orthographic processing of one language occurs. Past research suggests that there is influence from a bilingual's non-relevant language when she or he is processing words in the other language. One way of measuring such influence is achieved by varying the number of orthographic neighbors between languages and measuring the difference in reaction times to words with many and fewer cross-language neighbors. In this study, early and late English-Spanish bilinguals, who differed in experiences with their languages, responded to English and Spanish words in a progressive demasking task that differed by the number of orthographic neighbors (many or none) present in the other language. As expected, English words with many cross-language Spanish neighbors were responded to more slowly than English words with no cross-language Spanish neighbors. However, there was no significant difference in reaction times to Spanish words with many or no cross-language neighbors in English, which was unexpected. This pattern was similar in the two groups of bilinguals. Similar results were obtained in a control experiment with monolingual, English-speaking individuals, which suggests that the results obtained from the bilingual study might be due to some uncontrolled lexical variable (e.g., low imageability of specific English words with many Spanish neighbors).

INTRODUCTION

Visual word recognition occurs when an individual encounters a word and that word's orthographic representation is selected (or activated) among orthographically similar representations from the individual's mental lexicon (McClelland & Rumelhart, 1981). Recognition time is sensitive to a variety of factors, such as the word's frequency (Andrews, 1989), a word's imageability (Ferrand et al., 2011), and word length (Ferrand et al., 2011). Another factor affecting word recognition is the number of orthographically similar representations possessed by a word (Coltheart, Davelaar, Jonasson, & Besner, 1977). These orthographically similar words are known as neighbors and they differ from the word being encountered (the target word) by one letter respective of the position of the other letters (Coltheart et al., 1977)[1]. Research on orthographic neighbors in monolinguals suggests that there is activation of the target word and its neighbors when the target word is encountered. Such influence is measured through either an increase or decrease in reaction time, depending on the task (Carreiras, Perea, & Grainger, 1997).

Research on bilinguals provides opportunities to investigate issues of selectivity and storage that are absent in monolinguals (van Heuven, Dijkstra, & Grainger, 1998). Behavioral studies on how orthographically similar representations interact in late bilinguals have shown that words in one language activate neighbors in the other language (van Heuven et al., 1998). However, the way in which orthographically similar

[1] Neighbors may also be made by deleting or adding a letter respective of the other letter position (e.g., cat and cats); for the purpose of this study, the previous definition is used.

representations affect visual word recognition in early bilinguals has not been investigated and, thus, is the aim of the current research to investigate this phenomenon.

In the following, I will first describe how neighbors affect visual word recognition in monolinguals and how the findings from behavioral studies can be explained by the Interactive Activation model (McClelland & Rumelhart, 1997), which is a commonly accepted model of monolingual word recognition. Next, I will describe how cross-language neighbors affect visual word recognition in late bilinguals and how these findings can be explained by the Bilingual Interactive Activation model (van Heuven et al., 1998), which is an influential model of bilingual word recognition. Subsequently, I will describe findings from electrophysiological studies that show that cross-language neighbors may affect visual word recognition differently in late and early bilinguals. Finally, I will describe the proposed research and why it is necessary.

Visual Word Recognition in Monolinguals

As mentioned, orthographically similar words are known as neighbors and they are created when only one letter of a target word is changed (Coltheart et al., 1997). For example, the word "mourn" has one orthographic neighbor—"bourn." Words with many neighbors have larger (or denser) neighborhoods than words with fewer neighbors (belonging to sparser neighborhoods). The number of neighbors that a target word has constitutes its neighborhood density (ND). The effect of ND on word recognition depends on the experimental task being used (Carreiras et al., 1997).

The effect of neighborhood size on word recognition latencies is not entirely consistent across experimental paradigms (see Carreiras et al., 1997, for a review). For example, whereas words with higher ND elicit faster reaction times in lexical decision tasks (LDT) (Andrews, 1989; Holcomb, Grainger, & O'Rourke, 2002) and are most pronounced for words with low frequencies (Andrews, 1989), studies that have employed progressive demasking tasks (PDM) have typically found inhibitory effects (longer reaction times) of words with denser neighborhoods. A LDT typically requires participants to press one of two buttons (one dedicated to real words and the other to pseudowords) when stimuli (words and pseudowords) are presented visually. A PDM (Grainger & Segui, 1990) requires participants to indicate when they are able to recognize a word that is gradually being revealed from an occluding mask. The occluding mask and target word alternate in presentation. As time passes, the amount of time that the mask is shown decreases as the amount of time that the target is shown increases. The inhibitory effects of the PDM could reflect difficulty distinguishing between the target and similar words in the lexicon, a requirement that is not shared by LDTs, as LDTs only require individuals to indicate whether a word is a word or not a word. Thus, an individual might spend more time making sure that she or he has accurately identified the target (Grainger & Segui, 1990). Furthermore, studies using a PDM and LDT have shown that targets with neighbors of a higher frequency are recognized more slowly than targets with no neighbors of a higher frequency (Carreiras et al., 1997).

A model of visual word recognition that accounts for the previous results is the Interactive Activation (IA) model, which was first proposed by McClelland and Rumelhart (1981; see Figure 1 for an example of how the IA model works). As the model's architecture is shared with one of the bilingual models of word recognition considered later, it will be described in detail here.

According to this model, there are different levels through which letter strings presented visually are analyzed; these levels include feature, letter, and word. Processing occurs in parallel, which means that many letters may be processed simultaneously, and processing at different levels may occur simultaneously. Word recognition occurs when there is sufficient activation to meet a threshold for a given lexical representation. Activation is accomplished through connections between nodes (described as orthographic feature detectors). The connections between the nodes may be inhibitory or excitatory. The connections are dependent upon the similarity of the representations to the stimulus shown. Connections between levels that are matching (e.g., the letter *A* in the second letter position of the word *BARK*) are excitatory. Representations with no similar features to the stimuli shown are not activated.

In the model, there are inhibitory and excitatory connections between each of the levels. There are no connections between the feature nodes; however, at the word level (between word nodes only) and letter level (between letter nodes only), connections are inhibitory. Finally, each word representation in the lexicon has a resting activation level that differs from other word representations based on frequency, or the number of times a word appears in a body, or corpus, of texts. That is, words that are activated more often through more frequent exposure (higher frequency) have higher resting levels than those words with lower frequencies, according to the model (McClelland & Rumelhart, 1981). This aspect of the model accounts for frequency effects. This model also accounts for ND effects by suggesting that they result from the inhibitory connections between word nodes of orthographically similar words (neighbors) and target words (see McClelland & Rumelhart. The effects of the activation created by the target word and its neighbors affects word recognition latencies differently depending on the task (see pages 3 and 5 for examples). The existence of ND effects supports the IA's assumption that when a word is presented to an individual, that word's lexical representation is selected (or recognized) from a group of orthographically similar lexical representations in that individual's mental lexicon (the individual's collection of known words) (Grainger & Dijkstra, 1996; Grainger & Jacobs, 1996; Grainger & Ziegler, 2011; McClelland & Rumelhart, 1981; Perea, 1998; Perea & Rosa, 2000).

Visual Word Recognition in Bilinguals

Bilinguals, unlike monolinguals, have two lexica. Thus, it is possible that neighbors between and within languages could affect the processing of a target word in one language. Neighbors existing in a bilingual's non-target language are called cross-language (CL) neighbors. Cross-language neighborhood density (CLND) has been found to affect the processing of target words for late bilinguals (van Heuven et al., 1998). This finding suggests that representations in both languages are activated when participants read in one language. Within-language ND (WLND) effects, the effects of neighbors from the language being encountered, have also been found, but for the purpose of this review, only the results from the CLND studies will be discussed.

van Heuven et al. (1998) chose stimuli for their experiments that varied in the number of CL neighbors. These authors conducted four experiments implementing a blocked PDM, a mixed PDM, a generalized LDT, and an English (L2) LDT in order to understand how word recognition is affected by CLND in late bilinguals.

The blocked PDM was comprised of one block of Dutch stimuli (featuring Dutch words with many and few English neighbors) and one block of English stimuli (featuring

English words with many and few Dutch neighbors). The participants were comprised of late bilinguals differing in their level of L2 proficiency (low or high). The high proficiency group consisted of individuals who studied English or spent 6-12 months in a country in which English was spoken. The low proficiency group was comprised of individuals who majored in subjects other than English. Dutch had an inhibitory effect on the identification latencies of English targets. English also had an inhibitory effect on the identification of Dutch targets; however, this effect was modulated by proficiency and language presentation order. The effect of English neighbors on Dutch targets was not significant in low-proficiency bilinguals[2]. For high-proficiency bilinguals, the CLND effect showed a complex pattern, which depended on which language block was presented first: CLND had an inhibitory effect on the recognition of Dutch targets only when the Dutch block was presented first. Therefore, the pattern of CLND effects was different for the two languages. However, the authors did not directly compare Dutch and English targets but analyzed the languages separately. Explanations about the effects of each language are strained by analyzing the data this way, because one cannot say that one language exuded a greater effect than the other or vice versa.

In order to explain the order of presentation effect in proficient bilinguals, van Heuven et al. (1998) suggested that proficient bilinguals might be able to modulate the effects of the non-target language based on expectations. They hypothesized that the English lexicon might be more active at the beginning of the experiment, as participants

[2] The authors only report the absence of the two-way interaction between English ND and Order of Presentation; however, while describing the data, Dijkstra & van Heuven, 1998, write "The Dutch identification latencies of low-proficiency subjects in the first experiment were hardly affected by the presence of neighbors in English" (p. 196).

knew they would be tested on both languages, and less relevant later, when Dutch was presented as second block (p. 466). The authors ran additional analyses to test this hypothesis and analyzed each half of the block separately to assess whether CLND effects on Dutch targets would change during the block (that is, they included Part of Block as independent variable). The authors did not observe an effect of Part of Block. In discussing the results, Dijkstra & van Heuven (1998) remarked that over the second half of the first block, the effect of English neighbors on Dutch target identification became smaller: for individuals who saw the English block first, the effect of English neighbors on Dutch identification latencies went from being inhibitory in the first half of the Dutch block to being facilitatory in the second half (pp. 196-197). However, it must be noted that the authors did not find a significant interaction between Part of Block, English Neighborhood Size, and Order of Presentation. Therefore, Dijkstra and van Heuven's (1998) description of van Heuven et al.'s (1998) data was not substantiated by statistical analyses.

van Heuven et al.'s (1998) second experiment, a mixed PDM, consisted of one block featuring English and Dutch words. The stimuli were the same that were used in the first experiment and appeared in a random order. The authors do not remark on the English proficiency of these bilinguals. When the stimuli were presented in a random order, the effect of CLND for both languages was inhibitory. Unlike the findings from the first experiment, the CLND effect of English on Dutch targets was always inhibitory. The authors suggested that this finding could be due to English being relevant throughout the entire second experiment, which was not the case for English in the first experiment.

A generalized LDT was used for the third experiment of van Heuven et al. (1998). The stimuli used in this experiment were the same as those used in the second and were also shown in a random order. However, for this task, pseudowords that varied in the number of Dutch and English neighbors were added. The participants were required to press one button if the stimulus shown was a real word belonging to either English or Dutch and another if the stimulus shown was not a real word. Again, the experimenters did not state whether or not these individuals were highly or lowly proficient bilinguals. The CLND effect of Dutch on English word targets was inhibitory; however, there was no CLND effect of English on Dutch word identification latencies. The authors noted that CLND effects in the LDT were smaller than those of the PDM, which is not surprising as research suggests that the PDM is more sensitive to ND effects (Grainger & Segui, 1990). Pseudowords with many Dutch neighbors were responded to more slowly than those with fewer Dutch neighbors; however, the number of English neighbors did not have a significant effect on pseudoword latencies. The authors explain that for the rejection of pseudowords, the dominant language (Dutch) exerted the strongest effect, because it was the bilinguals' dominant language.

In the fourth experiment of van Heuven et al. (1998), an English (L2) LDT was implemented in order to ascertain whether pseudowords were sensitive to ND in English. The participants in this study consisted of English-speaking monolinguals and Dutch-English bilinguals. Again, the experimenters did not state whether or not these individuals were highly or lowly proficient bilinguals. The stimuli were comprised of the English stimuli and half of the pseudowords from their third experiment. The stimuli had small or large neighborhoods in Dutch or English. The monolinguals were not affected by the Dutch neighbors when English targets were shown; however, the responses of the bilinguals to the English words were inhibited by CLND, which supports the assumption that both languages are active during word recognition for bilinguals. Interestingly, for the bilinguals, Dutch neighborhood size did not significantly affect the responses to the pseudowords. For both bilinguals and monolinguals, response times were longer to pseudowords with many English neighbors than those with few English neighbors. The authors suggested that Dutch neighbors did not have an effect on pseudowords because Dutch was not relevant in this experiment. Thus, for pseudowords, the increased time to reject a pseudoword caused by the neighborhood density of real words is dependent on which language is most active. In the case of the fourth experiment, the most active language was English.

In summary, the CLND experiments from van Heuven et al. (1998) show that, for late bilinguals, orthographically similar CL neighbors are also activated when a target word in the other language is shown. This conclusion is suggested by the authors based on the findings that target words with many CL neighbors were responded to more slowly than those with fewer CL neighbors. Additionally, these results suggest that CLND effects are sensitive to the proficiency of the participant and the type of task being implemented.

Models of Written Word Recognition in Bilinguals

The central debates surrounding models of bilingual word recognition concern whether the lexica for the two languages are integrated or separate, and whether selection of representations from one language affect the recognition of representations in the other language (Dijkstra & van Heuven, 1998; Dijkstra & van Heuven, 2002a; Grainger, Midgley, & Holcomb, 2010; van Heuven et al., 1998). Thus, there are issues of storage of lexica (integrated or non-integrated) and selectivity of language activation (selective or non-selective). These issues have been addressed by models of bilingual access. The Bilingual Interactive Activation model (BIA; van Heuven et al., 1998; see Figure 2 for an illustration of the model) and its successor, the Bilingual Interactive Activation + model (BIA+; Dijkstra & van Heuven, 2002a; see Figure 3 for an illustration of the model), are models of bilingual word recognition in which lexical access is not language-selective and lexica are integrated. The non-selective activation feature implies that when a word in one language is presented, lexically similar words in the bilingual's other lexicon are also activated. For example, when the word "buzz" is encountered by an English-Spanish bilingual, not only is the English within-language neighbor "fuzz" activated, but the Spanish cross-language neighbor "buzo" is also activated.

The BIA model is an extension of the IA model. That is, the BIA model, like the IA model, features a feature level, a letter level, and a word level. However, unlike the IA model, the BIA model features an additional level called the language level, which contains the language nodes. These four levels comprise the word identification system. In addition to the resting levels being affected by frequency and recency of exposure (as in the IA model), L2 proficiency also affects resting levels (Dijkstra & van Heuven, 2002a). Thus, words from L1 typically have higher resting levels than words from L2 and are therefore activated faster for bilinguals who use their L1 more than their L2 and have a higher proficiency in their L1 than their L2.

In the BIA model, the language nodes serve four functions. First, the language nodes function as language tags, which specify to which language a word belongs.

Second, the language nodes receive activation from the words within a language. Third, with the activation that the language nodes receive from the word nodes, the language nodes serve as a control mechanism, modifying the amount of activation of the non-target language. In other words, the language nodes suppress the amount of interference from the non-target language by inhibiting the activation of the non-target language. Fourth, the language nodes receive contextual information from sources external to the identification system, which could affect the activation levels of the two languages. For example, if an individual knows that she or he will be seeing one block of English words and one block of Spanish words, then she or he will know which language to expect after the first block of words is encountered. Thus, if English is encountered first, then the individual would likely expect Spanish to be next and the activation of the English words may be modified (or suppressed) during the processing of the Spanish words.

The BIA model was able to account for a variety of findings; however, for the purpose of this paper, only the findings that are pertinent to this project will be discussed (see Dijkstra & van Heuven, 2002a, for the other findings). The BIA model was able to account for CLND effects observed in the van Heuven et al. (1998) study described previously. The BIA model accounted for the CLND effect of Dutch on English targets because the L2 targets were of a lower frequency than their Dutch neighbors. Lower frequency words are processed slower than higher frequency words, because the higher frequency words from L1 are activated first (their resting levels are higher from being used and seen more frequently), and therefore inhibit the activation of the lower frequency words in L2 (Dijkstra & van Heuven, 2002b). Furthermore, because the L1 neighbors were activated first, the language nodes for Dutch suppressed the activation of the English lexicon (the third function of the language nodes), thus inhibiting the recognition latencies for English target words (van Heuven et al., 1998).

The BIA model was also able to account for the changing CLND effect of English on Dutch identification latencies due to the presentation order observed in the blocked PDM. As mentioned, the effect of English neighbors was inhibitory when participants saw Dutch target words in the first block, whereas no CLND effects were found when Dutch words were presented in the second block. van Heuven et al. (1998) suggested that the English lexicon was most active at the beginning of experiment, as participants knew they were recruited for an experiment on bilingualism, and this would explain the inhibitory effect of English neighbors on Dutch targets when the Dutch block was presented first. The activation of English words would decrease after participants performed the English block. As a consequence, the effect of English neighbors on Dutch words would disappear when Dutch were presented in the second block. Therefore, van Heuven et al. (1998) suggested that proficient bilinguals were able to modify the amount of activation of L2 while they read L1 words. In the BIA model, such modulation is attained through the language nodes, as they collected contextual information that was outside the identification system.

The BIA+ model (Dijkstra & van Heuven, 2002) was proposed to address the flaws of the BIA model. These flaws included a lack of phonological and semantic representations, a lack of details for the representation of cognates and interlingual homographs, issues with the functions of the language nodes, the lack of information about how linguistic and nonlinguistic contexts affect the word recognition of bilinguals, the lack of information about how individuals complete tasks, and the lack of information as to how the identification of words is related to task requirements. The BIA+ model is physically different from the BIA model as the BIA+ model incorporates semantic and phonological representations, features a task/decision system, and restricts the functions of the language nodes.

The BIA+ model takes semantics and phonology of the stimuli into consideration by adding representations for each feature. The addition of semantics accounted for interlingual cognate effects and the addition of phonological processing accounted for interlingual homophone effects (Lemhöfer & Dijkstra, 2004). The BIA model did not explain these effects as that model only handled orthographic information.

The task/decision system (Task Schema) indicates the cognitive operations (schemas) that are required to fulfill an encountered task. The schemas are either configured as the participant performs the practice trials or they are acquired from memory if the task is familiar. This component of the model is separate from the identification system and does not affect the activation of the lexica. However, the Task/Decision system receives information about the activation from the identification system and response decisions are made based on that activation.

In the BIA+ model, the language nodes only function as language tags. Thus, the language nodes do not affect the activation levels of the lexica like they did in the BIA model. However, in language selection tasks, the language nodes aid the Task/Decision system in deciding which responses to make based on the activation of the language nodes. Cited evidence for the claim that the nodes do not modulate the activation within the identification system and that both languages are fully activated comes from unpublished data from Schulpen, Dijkstra, and Schriefers (in preparation, as cited in

Dijkstra & van Heuven, 2002). Schulpen et al. (in preparation) conducted three LDT experiments using three groups of bilinguals with unspecified language proficiencies (psychology students, Ph.D. students, and 15 and 17 year old high school students). Each experiment featured interlingual (English-Dutch) homographs (words that share orthography but have different meanings), control words in English that were matched based on different frequency groups, and purely English words that differed in frequency. The first experiment was an English LDT without Dutch words. The second experiment was an English LDT with Dutch words (that were not homographs) that needed to be rejected. The third experiment was a generalized LDT featuring Dutch and English words that were to be accepted. Results indicated that there was an inverse correlation between reaction times to English target words and English frequency for all three experiments. That is, reaction times to English target words decreased as English frequency increased. If the presence of Dutch items could directly affect the activation of the English lexicon (due to being activated first and suppressing the activation of the English lexicon), then the pattern of results would have been different for experiment two (when Dutch words were present). Specifically, one would expect, based on the BIA model, that reaction times to lower frequency English target words would have been even slower when Dutch words were present (experiment 2) than when Dutch words were not present (experiment 1). However, the results were not consistent with this prediction: the slopes of these experiments did not differ significantly. This result suggests that differences that exist between tasks are due to differing task demands and not changes in activation levels.

The BIA model accounts for the significant effect of language presentation order observed in van Heuven et al.'s (1998) first study as proficient late bilinguals being able to modulate the activation of the weaker lexica based on their expectations. However, the BIA+ model offers a different explanation for CLND only exerting an inhibitory effect on the recognition of Dutch targets when the Dutch block was presented first. According to the BIA+ model, both languages were always activated; however, the task/decision system was used to enhance participants' performance in the task by modifying decision criteria used to make responses (Dijkstra & van Heuven, 2002). It should be noted that Dijkstra and van Heuven (2002) do not explain how participants would modify their decision criteria when performing a PDM, so it is unclear how the task/decision system operates in this situation. In order to maximize performance (a function of the task/decision system) in a PDM, one might expect participants to take longer when responding to target words with many cross-language neighbors in order to be sure that they have identified the correct word and not a competing cross-language neighbor. This explanation is speculative, as it is not offered by Dijkstra and van Heuven (2002). The BIA+ and BIA models explain the finding that Dutch always had an inhibitory effect on English in the PDM similarly with the exception of the inhibitory function of the nodes given by the BIA model. Both models suggest that Dutch neighbors always had an inhibitory effect on English target identification latencies because of lateral inhibition occurring between the nodes of words and the higher resting activation levels of the Dutch lexicon based on it being used more and therefore being of a higher frequency than the English lexicon (Dijkstra & van Heuven, 2002b).

Regardless of the structural differences between the BIA models, predictions about the effect of CLND should be similar, because both models feature an identification system in which lexical representations from a bilingual's two languages are organized together and activation of the representations and orthographically similar representations from each language does not occur separately (Dijkstra & van Heuven, 2002b). This prediction is supported by van Heuven et al.'s (1998) finding that target words with many CL neighbors are responded to more slowly than target words with fewer CL neighbors. A major issue with both BIA models is that neither model addresses how differing linguistic experiences in bilinguals could affect word recognition. Evidence from electrophysiological studies suggests that visual word recognition may occur differently depending on linguistic experience.

Electrophysiological Findings of ND and CLND

It may seem somewhat problematic to assume that CLND affects word recognition in late and early bilinguals in the same way, because these groups of individuals have differing linguistic experiences (Baker, 2011). Late language learning typically occurs in a formal setting with an emphasis on explicit instruction (Baker, 2011). Furthermore, the late bilingual already has established lexical representations in one language and thus must integrate lexical representations of the other language. In contrast, an early bilingual may be exposed to both languages early in life and develop separate lexica, as suggested by the DevLex model (Hernandez, Li, & MacWhinney, 2005). These separate lexica may emerge as a result of early contextual cues (i.e., one parent speaks one language and the other speaks a different language), which aid in differentiating the two languages (Hernandez et al., 2005). The DevLex model has mainly been used to account for issues of production and has not been tested with orthographic word recognition (see Hernandez et al., 2005). Though the DevLex model has not received much attention, it is important because it is the only model that takes developmental differences into consideration. The BIA models do not take into consideration differing experiences of bilinguals and has primarily been used to explain visual word recognition in late bilinguals of differing proficiency (Grainger et al., 2010).

Findings from electrophysiological studies suggest that there could be a difference in early and late bilingual visual word recognition. This research has focused on the N400, a negative event-related potential (ERP), occurring between 300 and 500 ms, that is reported to be indicative of semantic and lexical processing (Kutas & Iragui, 1998). ERPs are measured using electroencephalography, which provides an index of cognitive processing produced by experimental manipulations by analyzing the electrical brain activity occurring during the cognitive processing that is being studied (van Hell & Tokowicz, 2010). This method of neural recording offers valuable information about the timing of cognitive processes (van Hell & Tokowicz, 2010).

In monolinguals, it has been found that target words with many orthographic neighbors evoke larger N400 amplitudes than those with fewer neighbors in both LDT and semantic categorization task (Holcomb et al., 2002). According to Holcomb et al. (2002), the larger N400 for words from larger neighborhoods reflects more overall activation created by the target word and its orthographically similar neighbors.

Midgley, Holcomb, van Heuven, and Grainger (2008) recorded the ERPs of proficient late French-English bilinguals (French being their first language and English being their second) during a go/no-go semantic categorization task where words from the two languages were presented in different blocks. The authors observed asymmetric electrophysiological effects (interaction between CLND and language): L2 targets with many L1 neighbors elicited more negative-going ERPs than L2 words with few neighbors in L1 during the 175-275 ms and 300-500 ms time windows. However, CLND effects for the L1 targets were found only in 300-500ms time frame, and this effect was smaller than the one observed for L2 targets. The authors suggested that the CLND effect began earlier (175-275 ms) for L2 targets with many neighbors in L1 because, although the bilinguals were proficient in both of their languages, their L1 was still more frequently used and thus affected the processing of the lesser frequently used language more than the less frequently used language affected L1.

Grossi, Savill, Thomas, and Thierry (2012) sought to replicate and extend the results of Midgley et al. (2008) by including both late proficient and early English (L1)-Welsh (L2) bilinguals; thus, their study afforded insights on how differences in language experience for proficient bilinguals might be manifested in ERPs. ERPs were recorded while participants completed a go/no-go semantic categorization task with words from the two languages presented in separate blocks. For late bilinguals, during the 175-300 ms time frame, words with many CL neighbors from both languages elicited more negative ERPs than words with fewer CL neighbors. During the 300-500 ms time frame, only L2 targets with many L1 neighbors elicited more negative ERPs than those with fewer L1 neighbors (i.e., this effect was only present for L2 targets during this time frame). These results partially replicated Midgley et al.'s (2008) findings. Interestingly, early bilinguals showed a different pattern of results. No effects were found during the 300-500 ms time frame. During the 175-300 ms time frame, Welsh targets with many CL neighbors elicited more positive ERPs than Welsh targets with fewer CL neighbors, whereas English targets with many CL neighbors elicited more negative ERPs than English targets with fewer CL neighbors. Thus, it is apparent that CLND may affect early and late bilinguals' visual word recognition differently. Grossi et al. (2012) suggested that the lack of N400 effects in early bilinguals might be due to an enhanced inhibitory control mechanism in these participants. Thus, early bilinguals might have been able to suppress the influence of the other language before the 300-500 ms time frame, resulting in no CLND effects in this time window. However, the categorization task employed by the authors did not provide behavioral data (Grossi et al., 2012); therefore, their study does not provide empirical evidence for the existence of such inhibitory mechanism at the behavioral level. The data from this study provide electrophysiological evidence suggesting that early bilinguals could possess enhanced inhibitory mechanisms and that early and late bilinguals could process influence from their non-relevant language differently.

The Present Study

The goal of the present study is to replicate and extend the findings of van Heuven et al.'s (1998) first study, which implemented a PDM with a blocked design. The present study extends the result of van Heuven et al. (1998) by testing a different group of bilinguals (early) as well as late bilinguals. Additionally, this study includes a different language pair (English and Spanish) and therefore a different stimulus list. It is important to replicate and extend van Heuven et al.'s (1998) study for two main reasons. First, their study is the only factorial study that examines the behavioral effects of CLND, which means that replication is warranted. Furthermore, van Heuven et al. (1998) did not directly compare the CLND effects in the two languages; as a consequence, claims about the asymmetrical nature of the effects must be interpreted with caution. Second, using early bilinguals as a comparison group allowed for behavioral information about whether the languages of bilinguals with differing linguistic experiences interact differently. Grossi et al.'s (2012) findings suggest that CLND affects late and early bilinguals differently; however, behavioral research has only focused on late bilinguals or on participants whose age of L2 acquisition is unknown (see Grossi et al., 2012). The BIA models do not make specific predictions based on the two different types of linguistic experiences. Thus, there is a need for future research to investigate how CLND behaviorally affects word recognition in early bilinguals.

Early and late English-Spanish bilinguals participated in a blocked PDM. The Spanish and English blocks featured target words with either many or few cross-language neighbors. The order in which each block appears was counterbalanced across participants.

Three main effects and three interactions were predicted. A main effect for CLND was predicted: target words with many CL neighbors were expected to be responded to more slowly than target words with fewer CL neighbors. Furthermore, a main effect for Language was expected, because both groups would be proficient in English, but only one group (early bilinguals) will be proficient in Spanish. Thus, English words were expected to be responded to more quickly than Spanish words. Finally, a main effect for Group was expected, as early bilinguals might be faster than late bilinguals based on their greater familiarity with both languages.

As for interactions, first, it was predicted that late bilinguals would respond to Spanish targets more slowly than to English targets, regardless of CLND, whereas a language effect was not expected in early bilinguals (Group x Language interaction) (see figure 4) . This prediction was based on different proficiency levels of the two groups of participants in the two languages. Late bilinguals would likely require more time to recognize target words in their L2 than their L1, because they are less familiar with their L2. Early bilinguals were expected to have similar response latencies for both languages.

Second, based on the BIA models, which suggest that the effects of L1 neighbors on L2 target words are stronger than L2 neighbors on L1 target words, and electrophysiological findings (e.g., Midgley et al., 2008) showing that L2 target words with many L1 neighbors elicited more negative-going N400s than L1 targets with many L2 neighbors, a three-way Language x CLND x Group interaction was expected (see figure 5). For late bilinguals, reaction times to Spanish targets with many English neighbors were expected to be more strongly inhibited by English neighbors than English target words with many Spanish neighbors (Language x CLND interaction). In contrast, for early bilinguals, a main effect of CLND was expected based on the BIA models: target words with many CL neighbors were expected to be responded to more slowly than target words with fewer CL neighbors. A symmetric CLND effect was expected for early bilinguals based on equal proficiency and experience with their languages. In other words, one language should not be stronger (due to higher resting levels, higher frequency, frequency of usage, etc.) than the other as is seen in late bilinguals. Alternatively, based on Grossi et al.'s (2012) electrophysiological findings that CLND did not modulate the N400, early bilinguals might not respond differently to targets with many or fewer CL neighbors (see figure 6). The lack of behavioral CLND effect in early bilinguals would suggest the existence of an enhanced inhibitory control mechanism allowing them to inhibit the interference from the non-relevant language, as speculated by Grossi et al. (2012), or separate lexica (Hernandez et al., 2005).

Third, based on the findings of van Heuven et al. (1998) and the equal proficiencies of the languages of early bilinguals, a four-way Group x Order x Language x CLND interaction was predicted (see figure 7). For late bilinguals, a CLND x Order x Language interaction was expected based on van Heuven et al.'s (1998) findings: the inhibitory effect of L2 CL neighbors on L1 targets would be significant only when L1 target words are presented in the first block. van Heuven et al. (1998) suggested that late bilinguals were able to modulate the amount of interference from their weaker language based on already seeing L2 in the first block and thus expecting to see words in their L1 in the second block. In contrast, based on the BIA models, it was predicted that early bilinguals would show an Order x CLND interaction, as the inhibitory effect of CLND is expected to be stronger for the first block than the second block regardless of language. Alternatively, it may be the case that there will be no effect of the other language on identification latencies of the language featured in the second block. Once an early bilingual has completed the first block, she or he, may be able to modulate the amount of interference from the non-target language.

METHOD

Participants

The data from 26 late bilinguals and 30 early bilinguals comprised the analyses for the behavioral and demographic data. The translation data of two of these participants (one early bilingual and one late bilingual) were not included in the analyses due to insufficient responses, which were likely caused by the participants not understanding the task. Additionally, data from two participants were not included in analyses due to the individuals not meeting the age of acquisition requirement, and one participant was excluded from the analyses due to the PDM software malfunctioning. Demographic characteristics of the 56 participants are available in Table 1. All of the participants were students at a New York state college and were recruited through classroom information sessions and through the implementation of information flyers dispersed around the university. Late bilinguals were required to have English as native language and to have learned Spanish after puberty (for this experiment, the age requirement was 11 years, but data from one participant who learned Spanish at the age of 10 years were included). Early bilinguals were required to have learned Spanish and English before five years of age. All of the participants had normal or corrected-to-normal vision, were between the ages of 18 and 40, had no history of developmental reading disabilities (i.e., dyslexia), and had familiarity with only Spanish and English. Furthermore, participants were given ten dollars for their participation.

All of the early bilinguals reported learning Spanish from birth. As for the age at which the early bilinguals reported learning English, 13 reported learning English from birth, two from two years, one from three years, seven from four years, and seven from five years (*M* = 2.33, *SD* = 2.20). Participants were asked to indicate their perceived proficiency in speaking, comprehending speech, and reading in Spanish and English (see Table 2 for a summary of the frequency data for early bilinguals). Early bilinguals indicated that they were exposed to English, currently and on average, 65.33% (*SD* = 15.37) of the time and to Spanish 34.67% (*SD* = 15.37) of the time. When given the option to read in English or Spanish, early bilinguals indicated that they would choose to read in English 84.83% (*SD* =14.36) of the time and Spanish 15.17% (*SD* = 14.36*)* of the time. When given the option to speak in English or Spanish with someone of equal proficiency in both languages, early bilinguals reported choosing to speak in English 68.33% (*SD* = 23.94) of the time and Spanish 31.67% (*SD* = 23.94) of the time.

All of the late bilinguals reported that they learned English from birth. As for the age at which late bilinguals began acquiring Spanish, participants reported beginning at various ages: 10 (1), 11 (6), 12 (8), 13 (8), 14 (1), 17 (1), and 19 years (1) (*M* = 12.54, *SD* = 1.88). Participants were asked to indicate their perceived proficiency in speaking, comprehending speech, and reading in Spanish and English (see Table 3 for a summary of the frequency data for late bilinguals). Late bilinguals indicated that they were currently and on average exposed to English 80.96% of the time and to Spanish 19.03% (*SD* = 13.42) of the time. When asked about the percentage of time that late bilinguals would choose to read a text in either Spanish or English, these individuals indicated that they would read a text in English 87.60% (*SD* = 14.94) of the time and Spanish 12.40% (*SD* = 14.94) of the time. This preference was not different from the one reported by late bilinguals, Group x Language interaction, F (1, 52) = .48, p = .49, ηp^2 = .01. When asked to indicate the percentage of time that they would choose to either speak in Spanish or English with an individual equally proficient in both languages, late bilinguals indicated that they would choose to speak in English 75% (*SD*= 18.55) of the time and Spanish 25% (*SD* = 18.55) of the time.

Finally, participants were asked to rate how proficient they perceived themselves in reading English and Spanish (0-10 scale). The difference in perceived competence for reading in English (*M* = 9.17, *SD* = 1.04) was significantly higher than that for Spanish (*M* = 7.45, *SD* = 1.64) for early bilinguals, $t\ (29) = 5.77$, $p < .001$. Late bilinguals also rated themselves as being more competent readers in English (*M* = 9.52, *SD* = 1.16) than Spanish (*M* = 7.24, *SD* = 1.34), $t\ (25) = 8.52$, $p < .001$. The differences between the two groups in their perceived competences in reading in English and Spanish did not differ significantly, Group x Language interaction, $F\ (1, 52) = 1.91$, $p = .17$, $\eta p^2 = .04$.

Stimuli and Materials

English and Spanish words were selected from the Cross-Linguistic Easy-Access Resource for Phonological and Orthographic Neighborhood Density database (Marian, Bartolotti, Chabal, & Shook, 2012), which can be accessed through the following website: http://clearpond.northwestern.edu. The participants were presented with two blocks (one Spanish block and one English block) of stimuli. Each experimental block was preceded by a block of 12 practice trials in the language of the language of the following experimental block. Each block was comprised of 40 words, 20 of which had high CLND and the remaining 20 had low CLND (See Appendix A for a list of the experimental and Appendix B for the practice stimuli). Thus, there were 20 high CLND English words, 20 low CLND English words, 20 High CLND Spanish words, and 20 low

CLND Spanish words. Table 2 displays the means and standard deviations of the frequency, length, type bigram frequency (BF), WLND, and CLND of the stimuli. The stimuli were presented in white, upper-case, 24-point Courier font against a black background. For this experiment, pound symbols were used as the mask. For each word, the mask consisted of two more pound symbols than the number of letters comprising the target word being displayed (e.g., the word BARK would be presented with a mask contained six pound symbols-- ######).

The frequency, length, bigram frequency, and WLND were matched across all four stimuli blocks (all *p*'s > .45). There was a significant main effect of CLND, $F = 192.67$, $p < .001$, indicating that high CLND words for both languages differed significantly from their respective low CLND words.

The Language Experience and Proficiency Questionnaire (LEAP-Q; Marian, Blumenfeld, & Kaushanskaya, 2007) was administered to participants to gather information about their demographics and proficiency in and experience with their languages (see Appendix C for the LEAP-Q). This questionnaire is completed on the computer and can be found at the following website: http://comm.soc.northwestern.edu/bilingualism-psycholinguistics/leapq/. The linguistic information of interest from the LEAP-Q included the participants' perceived dominance in their two languages (i.e., whether English is more dominant than Spanish or vice versa); which language they learned first; the average and current percentage of time (out of 100) the participants are exposed, choose to speak to people who are equally proficient in, and choose to read in Spanish and English; age at which they began acquiring Spanish and English; and their perceived proficiencies in speaking, understanding speech, and reading in Spanish and English.

A translation task was used to gain an objective measure of the participants' proficiencies in Spanish and English. The words that comprised the translation task were those used in the experiment.

An additional demographics questionnaire (see Appendix D for the demographics questionnaire) was used to collect information about participants' gender, age, first language, what other languages are known, and whether or not participants are fluent in those other languages. The Edinburgh Assessment of Handedness (Oldfield, 1971) was used to collect information about the handedness of participants.

Procedure

Once participants gave written consent, they were guided to a sound-attenuated room where they were situated by the experimenter for the experiment. The participants sat 67 cm from a computer monitor that displayed the stimuli. Next, the experimenter placed a metal bar, which was affixed to the walls of the room, at the participants' forehead and requested that the participants keep their forehead rested against the bar to ensure that their distance from the screen remained constant for the duration of the experiment. Once the participants were situated for the experiment, they were given instructions for the experiment in English. After reading the instructions, the participants were given time to ask any questions about the requirements of the PDM (Dufau, Stevens, & Grainger, 2008).

Instructions were given in the language of the block (e.g., "press space bar" for the English block and "Presione la barra espaciatora" for the Spanish block). Once participants pressed the space bar, a fixation point (+) appeared in the middle of the screen. After 500 ms, the fixation point was replaced by the mask, which alternated in appearance with the target word. After each cycle, the time that the mask appeared decreased by 15 ms and the duration of time that the target word was shown increased by 15 ms. The mask was always followed by the target word (first appearing for 15 ms) and first appeared for 300 ms. The next cycle featured the mask for 285 ms and the target for 30 ms. This continued until the participant indicated that she or he recognized the word or until six seconds passed. Once participants pressed the space bar, indicating that they recognized the target word, a prompt with the word "response" appeared in the middle of the screen, at which point, participants entered the word that they saw and pressed enter once they were done typing. After pressing enter, the next word mask-target pair began. The order of language blocks was counterbalanced across participants.

After completing the PDM, the participants filled out the LEAP-Q, completed the translation task, and completed the handedness questionnaire. After all of the data were collected, the participants were fully compensated for their time, and thanked for participating in the study. The entire experiment typically lasted between 45 and 60 minutes.

RESULTS

Data Analysis

Reaction times for when participants indicated that they recognized a word by making a button press were recorded. These recorded times were averaged for each participant and the reaction times of the test conditions for each language were averaged separately. Following van Heuven et al. (1998), incorrect responses were not included in the reaction time analysis. Language (English and Spanish) and CLND (high and low) were within-subjects variables, while Order of Presentation (Spanish followed by English or English followed by Spanish) and Group (Early or Late) were between-subjects variables. Thus, the data collected from this experiment required a 2x2x2x2 mixed split-plot factorial analysis of variance (ANOVA). Significant interactions were explored with follow-up analyses.

Reaction Times

Two of the three predicted main effects were significant. First, words with many CL neighbors (M = 1618.36, SD = 332.30) were recognized more slowly than words with fewer CL neighbors (M = 1562.13, SD = 330.96) (main effect of CLND), F (1, 52) = 16.97, $p < .001$, $\eta p^2 = .25$. Furthermore, Spanish words (M = 1660.57, SD = 306.63) were recognized more slowly than English words (M = 1519.93, SD = 342.85) (main effect of Language), F (1, 52) = 25.89, $p < .001$, $\eta p^2 = .33$. However, early bilinguals and late bilinguals did not differ in reaction times, $p = .62$.

Two interactions[3] resulted significant. First, a Language x CLND interaction was found, *F* (1, 52) = 30.80, $p < .001$, $\eta p^2 = .37$ (see Figure 8 for this interaction). A paired samples t-test indicated that English high CLND words (*M* = 1587.59, *SD* = 354.86) were recognized more slowly than English low CLND words (*M* = 1452.26, *SD* = 319.35), *t* (55) = 6.14, $p < .001$. Recognition times between high CLND Spanish words (*M* =1649.14, *SD* = 308.22) and low CLND Spanish words (*M* = 1672.01, *SD* = 307.40) did not differ significantly, *p* = .17. This effect did not interact with Group, indicating that this pattern was similar in the two groups of bilinguals, *p* = .32.

Second, there was a significant interaction between Order and Language, *F* (1, 52) = 6.23, $p < .05$, $\eta p^2 = .11$ (see Figure 9 for this interaction). A paired samples t-test revealed that participants who responded to Spanish words in the first block responded more slowly to the Spanish stimuli (*M* = 1725.39, *SD* = 316.16) viewed in the first block than the English stimuli (*M* = 1520.73, *SD* = 343.05) viewed in the second block, *t* (29) = 5.85, $p < .001$. When participants viewed English first, the difference between reaction times to English in the first block (*M* = 1519.00, *SD* = 315.03) and Spanish in the second block (*M* = 1585.79, *SD* = 270.83) was not significant, *p* = .11.

Accuracy

There were no a priori predictions made for the response results (percentages out of 100) of the PDM. There was a significant main effect of CLND, *F* (1, 52) = 4.03, *p* = .05, $\eta p^2 = .07$: high CLND words (*M* = 93.61, *SD* = 7.57) were typed less accurately than

[3] One English word, "Arena," was later discovered to be a false cognate in Spanish (meaning "Sand"). Results for "Arena" were removed and analyses were conducted again. None of the interactions or main effects changed as a result of removing this word; therefore, the results with the influence of "Arena" are reported.

low CLND words (*M* = 94.82, *SD* = 8.05). This main effect was qualified by an interaction with Language, F (1, 52) = 4.48, $p < .05$, $\eta p^2 = .08$ (see Figure 10 for this interaction). Follow-up analyses indicated that English low CLND words (*M* = 95.98, *SD* = 5.67) were typed more accurately than English high CLND words (*M* = 93.30, *SD* = 7.99), t (55) = -3.37, $p < .01$. The difference between accuracy scores for Spanish high CLND words (*M* = 93.93, *SD* = 7.18) and Spanish low CLND words (*M* = 93.66, *SD* = 9.80) was not significant, $p = .80$.

It is important to note that typing accuracy in this situation is not necessarily a measure of interference from the nontarget language, as the PDM task was blocked by language (i.e., only one language was relevant during each block). For the frequencies of each typing error made, refer to tables 5 through 12.

Translation Task

Errors from the translation task were categorized into six groups—semantic, morphological, phonetic, orthographic, no response, and language interference (see Table 13 for examples of errors). Responses varying from the correct spelling by one letter of the translation were accepted as correct; however, if changing one letter created a word in the language that one was translating from (language interference error), then those translations were not accepted. If individuals did not include an accent mark, which happened frequently, and they had an additional incorrect letter in a word, then the word was counted as incorrect. Conjugated forms (in the imperative) of translations were accepted as correct. The majority of individuals who provided a translation response to “Abajo” provided “Under” or “Underneath” instead of the expected translation, which is “Beneath;” therefore, those translations were accepted as correct. Additionally, the majority of individuals who provided translation responses to the word "Filth" provided "Sucia" or "Sucio," which means "Filthy," instead of the translation—"Suciedad," so those responses were accepted as correct.

Two independent samples t-tests indicated that there were significant differences between early and late bilinguals for the number of correct translations (out of 40, the number of words for which to provide translations, for each language) when translating from Spanish to English, t (52) = -6.57, $p < .001$, and from English to Spanish, t (52) = -3.00, $p < .01$. Early bilinguals (M = 30.17, SD = 4.29) translated more accurately than late bilinguals (M = 21.72, SD = 5.16) from Spanish to English. Early bilinguals (M = 11.69, SD = 4.27) also translated more words accurately from English to Spanish than late bilinguals (M = 8.48, SD = 3.48).

DISCUSSION

The main goal of the present study was to replicate and extend the behavioral effects of CLND on word recognition found by van Heuven et al. (1998) by comparing these effects in early and late bilinguals. Furthermore, this study was conducted to understand how CLND affects early bilinguals at the behavioral level, as the electrophysiological data from Grossi et al. (2012) suggested that late and early bilinguals could exhibit behavioral differences based on differences in ERPs related to CLND (i.e., the N400) observed between the two groups.

As expected, high CLND words were recognized more slowly than low CLND words and English words were recognized more quickly than Spanish words (based on both groups being proficient in English but one group being more proficient in Spanish). However, contrary to our predictions, there was no difference between groups: early bilinguals did not respond more quickly to words than late bilinguals.

As expected, the interaction between Language and CLND was significant for reaction times. However, the pattern of the effects was different from the predicted one. No significant difference in reaction times was found between high and low CLND Spanish words; furthermore, there was a significant difference in reaction times between high and low CLND English words. This pattern was similar in the two groups (the interaction between Language, CLND, and Group, was not significant).

It is difficult to interpret these data based on the models of bilingual lexical access discussed in the Introduction. Based on the BIA models and the behavioral data from van Heuven et al. (1998), it was predicted that the high CLND Spanish words would elicit longer reaction times than low CLND Spanish words in late bilinguals, because these participants were more proficient in English (L1) than Spanish (L2), and English neighbors should have influenced the processing of Spanish words. The finding that English words with many CL neighbors were responded to more slowly than English words with no CL neighbors was expected, but it was predicted, based on the BIA models and van Heuven et al. (1998), that this difference would be smaller than the difference between high and low CLND Spanish words, as these participants were less proficient in Spanish. For early bilinguals, there were two alternative predictions made in relation to CLND effects. According to the BIA models, CLND effects would be symmetrical, as early bilinguals are highly familiar with both languages and therefore the influence of each language on processing in the other language would be similar. Alternatively, based on Grossi et al.'s (2012) electrophysiological findings, no CLND effects were expected in this group. Grossi et al. (2012) found different patterns of ERPs in early and late bilinguals. While late bilinguals produced asymmetrical components (larger N400s when processing L2 words than when processing L1 words suggesting more influence from L1 to L2 than L2 to L1), early bilinguals did not show a modulation of the N400 due to CLND. The authors suggested that this could be indicative of early bilinguals possessing inhibitory control mechanisms that would allow them to modulate the influence from each language when processing in the other language.

Based on previous work on neighborhood effects in bilinguals (Grossi et al., 2012; van Hueven et al., 1998), the lack of group differences in the present study was surprising. In order to understand if there could have been some extraneous variable driving the CLND x Language interaction, a group of control participants only proficient in English was recruited to participate in the PDM experiment. If the difference between high and low English CLND words was due to the number of Spanish neighbors, then monolinguals should show no effect of CLND for English words, because these individuals do not know Spanish and processing in English should not be affected by Spanish neighbors. Similar results (i.e., CLND x Language interaction) for bilinguals and control participants would entail that some aspects of the high CLND English words drove this effect. The procedure used for the monolingual participants was the same as the procedure for the bilingual participants. The recruitment of these participants was different from the one followed for bilingual participants; monolinguals were recruited through an online participation site and participants received class credit for their participation.

The data from 24 English-speaking monolinguals (see table 14 for demographic information pertaining to these participants) were analyzed. Language was significant as main effect, F (1, 22) = 47.70, p < .001, $\eta p^2 = .68$: RTs to English words (M = 1379.60, SD = 212.62) were faster than reaction times to Spanish words (M = 1808.50, SD = 303.25). Furthermore, there was a significant main effect of Order, F (1, 22) = 4.34, p = .05, $\eta p^2 = .17$: RTs were faster when the English block of stimuli (M = 1512.53, SD = 310.79) was presented first than when the Spanish block of stimuli was presented first (M = 1675.57, SD = 347.76). Finally, there was a significant interaction between Language and CLND, F (1, 22) = 21.09, p < .001 (see Figure 11 for this interaction). Follow-up paired samples t tests indicated that Spanish high CLND words (M = 1779.35, SD = 289.29) were recognized more quickly than Spanish low CLND words (M = 1837.64, SD = 320.08), t (23) = -2.24, p < .05, and that English high CLND words (M = 1431.79, SD = 212.04) were recognized more slowly than English low CLND words (M = 1327.42, SD = 204.30), t (23) = 4.98, p < .001.

The results of the typing accuracies for monolinguals revealed two significant main effects and one significant interaction. First, there was a main effect of Language, F (1, 22) = 7.74, $p < .05$, $\eta p^2 = .26$: English words (M = 93.54, SD = 7.92) were typed more accurately than Spanish words (M = 87.50, SD = 13.64). Second, there was a main effect of CLND, F (1, 22) = 4.76, $p < .05$, $\eta p^2 = .18$: high CLND words (M = 89.69, SD = 10.28) were typed less accurately than low CLND words (M = 91.35, SD = 12.66). Finally, there was a significant interaction between Language and CLND, F (1, 22) = 10.99, $p < .01$, $\eta p^2 = .33$ (see Figure 12 for this interaction). Two paired samples t tests revealed significant differences in typing accuracy between Spanish high and Spanish low CLND words, t (23) = 2.19, $p < .05$, and English high and English low CLND words, t (23) = -3.66, $p < .01$. High CLND Spanish words (M = 89.17, SD = 11.48) were typed more accurately than low CLND Spanish words (M = 85.83, SD = 15.58) and high CLND English words (M = 90.21, SD = 9.15) were typed less accurately than low CLND English words (M = 96.88, SD = 4.62).

The significant interaction between Language and CLND for monolinguals suggests that there could be some extraneous lexical variable that drove the CLND effect for the English stimuli in the present study. As was true for the bilinguals of this study, the monolingual participants responded more slowly to the high than the low CLND English words. The monolingual participants also responded more slowly to low CLND Spanish words than to high CLND Spanish words; the precise mechanism driving this effect is unclear, but it might also be driven by non-controlled orthographic or lexical factors.

Similarly to bilinguals, monolinguals also translated more accurately from Spanish to English *(M* = 6.29, *SD* = 4.01) than from English to Spanish (*M* = .89. *SD* = 1.62), t (23) = 8.29, $p < .001$. Importantly, the three groups performed significantly different on the translation task (Group, F (2, 75) = 184.66, $p < .001$, $\eta p^2 = .83$). Post hoc analyses revealed that when translating from Spanish to English, early bilinguals translated more words accurately than late bilinguals and monolinguals, and late bilinguals translated more accurately than monolinguals (all *p*'s < .01). A similar pattern was found for translations from English to Spanish F (2, 75) = 69.00, $p < .001$, $\eta p^2 = .65$ (all *p*'s < .01). Therefore, the three groups demonstrated different levels of proficiency in Spanish (operationalized as vocabulary), as expected based on age of acquisition for Spanish.

As with the bilinguals, the typing responses and frequencies from the PDM for the monolinguals were organized (see Tables 15 through 18 for these data). The analysis of typing errors suggest that these errors did not necessarily reflect interference from the nontarget language, because the monolinguals seemed to struggle with typing some of the same high CLND English words as the bilinguals. For example, commonly misspelled high CLND English words (words with at least three misspellings) for early bilinguals included “Cellar,” “Fella,” “Fiery, “ Leery,” “Liable,” “Posse,” “Quite,” and “Rogue”; commonly misspelled high CLND English words for late bilinguals included “Fella,” “Leery,” “Liable,” “Rascal,” and “Rogue”; and for monolinguals, commonly misspelled high CLND English words included “Arena,” “Cellar,” Crib,” “Fella,” “Leery,” “Posse,” “Quite,” and “Rogue.” Furthermore, it appears that some of errors recurred across groups (e.g., “label” for “liable, ” “pose” for “posse”) and might reflect the effect of higher frequency of different types of within-language neighbors (e.g., deletion neighbors). A lexical commonality of some of these words is low imageability. Previous research has shown that reaction times from PDMs are sensitive to how imageable a word is (Ferrand et al., 2011); specifically, low imageability values are associated with longer RT. It is therefore possible that, across groups, RT for high CLND words were slower than RT for low CLND words in English because of higher imageability. Unfortunately, imageability values for many of the words used in the present experiment are not available; therefore, the role of this factor in the present study cannot be tested. As typing accuracies alone do not account for differences in reaction times between high and low CLND English words, an item analysis will be necessary to assess whether some unaccounted word characteristics can explain the results for reaction times. Similarly, an item analysis will be beneficial to understand what drove the difference in RT between high and low CLND Spanish words in monolinguals.

Unexpectedly, for reaction times of the bilingual participants, there was a significant interaction between Order and Language. The only a priori prediction involving influence of Order was a four-way interaction between Group, Order, Language, and CLND, in which it was predicted that late bilinguals would exhibit a CLND x Order x Language interaction and early bilinguals would show either no effect of Order or an Order x CLND interaction. For late bilinguals, based on the findings of van Heuven et al. (1998), CLND effects of Spanish on English targets were predicted to only be significant when English words were presented in the first block and CLND effects of English on Spanish targets were expected to always be inhibitory regardless of which language was presented first. Based on suppositions of enhanced inhibitory control mechanisms (see Grossi et al., 2012), for early bilinguals, it was either expected that the inhibitory effect of CLND would be stronger for the language presented in the first block than the language presented in the second block or that there would be no effect of CLND for the language presented in the second block. For bilinguals who responded to Spanish words in the first block, reaction times to Spanish stimuli were slower than the reaction times to English stimuli, whereas no differences in RT between the two languages were observed when English was presented first. Future research will need to explore this pattern of results, unexpected based on models of word recognition in bilinguals.

Limitations and Future Directions

A possibility as to why CLND effects were not found in this experiment might be due to the number CL neighbors present for the high CLND stimuli groups. Although high and low CLND stimuli groups differed in terms of CLND, the number of CL neighbors in the high CLND conditions might not have been large enough to evoke effects. All of the stimuli in the low CLND stimuli groups had no CL neighbors. The mean number of CL neighbors in the high English CLND stimuli group was 2.70 and the mean number of CL neighbors in the high Spanish CLND stimuli group was 2.85 (these numbers were not significantly different). The number of CL neighbors present for high CLND words in past studies has been higher than that of the present study. For example, the mean number of CL neighbors for the Dutch and English high CLND stimuli of van Heuven et al. (1998) was 3.50; for Midgley et al. (2008), the mean number of CL neighbors for high CLND English words was 5.90 and the mean number of CL neighbors for high CLND French words was 7.80; and for Grossi et al. (2012), the mean for both Welsh and English high CLND words was 7.83. Thus, it might be important to replicate this study by including stimuli with higher CLND.

The pattern of results in the PDM experiment revealed no substantial differences in performance between the two groups of bilinguals. The two groups differed in terms of age of acquisition for Spanish; furthermore, early bilinguals were better at translating than the late bilinguals. However, being able to translate from one language to another is a measure of vocabulary and does not necessarily reflect orthographic and lexical processing. Self-report data from the LEAP-Q showed little differences between the groups in terms of language dominance. For example, all of the late bilinguals reported being more dominant in English than Spanish. As for the early bilinguals, only two participants (out of 30) listed Spanish being their more dominant language. Furthermore, both groups reported a preference for reading in English if they had a choice between the two languages. Finally, participants in both groups rated themselves as more competent in English than Spanish in terms of reading abilities. These data suggest that late and early bilinguals in this study might not have differed substantially in terms of reading experience. This similarity might explain why no group differences were found in this study.

To our knowledge, this study was the first one to attempt to measure behavioral differences elicited by CLND in bilinguals who differ in their experiences and proficiencies with their two languages. The only other known factorial behavioral CLND study was conducted by van Heuven et al. (1998) and only measured these effects in late bilinguals and, to our knowledge, there are no published replications of these behavioral data. Furthermore, the participants in van Heuven et al.'s (1998) study were familiar with Dutch and English; therefore, these behavioral results have only been found with this language pair. It might be the case that their results are not generalizable to English-

Spanish bilinguals. Interestingly, two more recent nonfactorial studies (de Groot, Borgwaldt, Bos, & van den Eijnden, 2002; Lemhöefer et al., 2008) failed to find an effect of L1 neighbors on L2 targets in late bilinguals. Because many different stimuli (e.g., more than a thousand in Lemhöefer et al., 2008) and many different types of within-language influences are at work in these studies, it is possible that smaller cross-language effects did not have a chance to surface. Thus, replication of these behavioral results in controlled factorial designs is still warranted. Future research should attempt to measure CLND effects in early and late bilinguals with a different set of stimuli as past electrophysiological data (i.e., Grossi et al., 2012) suggests that there could be differences in how CLND effects are manifested behaviorally. Finally, although the present data do not show evidence of substantial differences between early and late bilinguals, it is suggested that the BIA and BIA+ models take into consideration how differences in terms of linguistic experiences between groups of bilinguals could affect word recognition. Such revisions would help create a developmentally more valid model of bilingual word recognition, one that aims at understanding of how various experiences with multiple languages (e.g., heritage bilingualism, early balanced bilingualism) affect the way bilinguals read.

REFERENCES

Andrews, S. (1989). Frequency and neighborhood effects on lexical access: Activation or search? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *15*(5), 802-814.

Baker, C. (2011*). Foundations of Bilingual Education and Bilingualism*, V. Bristol, UK: Multilingual Matters.

Carreiras, M., Perea, M., & Grainger, J. (1997). Effects of orthographic neighborhood in visual word recognition: Cross-task comparisons. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23*, 857-871.

Coltheart, M., Davelaar, E., Jonasson, J. T., & Besner, D. (1977). Access to the internal lexicon. In S. Dornič (ed.), *Attention and performance*, VI (pp. 535-555). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

de Groot, A., Borgwaldt, S., Bos, M., & van den Eijnden. (2002). Lexical decision and word naming in bilinguals: Language effects and task effects. *Journal of Memory and Language, 47*, 91-124. doi:10.1006/jmla.2001.2840

Dijkstra, T., & van Heuven, W. J. (2002a). The architecture of the bilingual word recognition system: From identification to decision. *Bilingualism: Language and Cognition, 5*, 175-197. doi: 10.1017/S1366728902003012

Dijkstra, T., & van Heuven, W.J. (2002b). Authors' response: Modeling bilingual word recognition: Past, present and future. Bilingualism. *Language and Cognition, 5*, 219-224. doi: 10.1017/S1366728902238017

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

Dufau, S., Stevens, M. & Grainger J. (2008). Windows executable software for the progressive demasking task (PDM). *Behavior Research Methods, 40(1), 33-37.* doi: 10.3758/BRM.40.1.33

Ferrand, L., Brysbaert, M., Keuleers, E., New, B., Bonin, P., Méot, A., … Pallier, C. (2011). Comparing word processing times in naming, lexical decision, and progressive demasking: Evidence from Chronolex. *Frontiers in Psychology*, *2*, 306. doi:10.3389/fpsyg.2011.00306

Grainger, J., & Dijkstra, T. (1996). Visual word recognition: Models and experiments. In T. Dijkstra & K. De Smedt (Eds.), *Computational psycholinguistics: Symbolic and connectionist models of language processing* (pp. 139-165). Bristol, PA: Taylor & Francis.

Grainger, J., & Jacobs, A. M. (1996). Orthographic processing in visual word recognition: A multiple read-out model. Psychological review, 103(3), 518-565.

Grainger, J., Midgley, K., & Holcomb, P.J. (2010). Re-thinking the bilingual interactive-activation model from a developmental perspective (BIA-d). In M. Kail & M. Hickmann (Eds.), *Language acquisition across linguistic and cognitive systems* (pp. 267-284). New York: John Benjamins.

Grainger, J., & Segui, J. (1990). Neighborhood frequency effects in visual word recognition: A comparison of lexical decision and masked identification latencies. *Perception and Psychophysics, 47* (2), 191-198.

Grainger, J., & Ziegler, J. C. (2011). A dual-route approach to orthographic processing. *Frontiers in Psychology, 2* (54). doi: 10.3389/fpsyg.2011.00054

Grossi, G., Savill, N., Thomas, E., & Thierry, G. (2012). Electrophysiological cross-language neighborhood density effects in late and early English-Welsh bilinguals. *Frontiers in Psychology, 3* (408). doi: 10.3389/fpsyg.2012.00408

Hernandez, A.E., Li, P., & MacWhinney, B. (2005) The emergence of competing modules in bilingualism. *Trends in Cognitive Sciences, 9* (5), 220-225. doi:10.1016/j.tics.2005.03.003

Holcomb, P. J., Grainger, J., & O'Rourke, T. (2002). An electrophysiological study of the effects of orthographic neighborhood size on printed word perception. *Journal of Cognitive Neuroscience, 14*(6), 938-950.

Kutas, M., & Iragui, V. (1998). The N400 in a semantic categorization task across 6 decades. *Electroencephalography and Clinical Neurophysiology, 108*(5), 456-471.

Lemhöfer, K., & Dijkstra, T. (2004). Recognizing cognates and interlingual homographs: Effects of code similarity in language-specific and generalized lexical decision. *Memory & Cognition*, *32*(4), 533-550. doi: 10.3758/BF03195845

Lemhöfer, K., Dijkstra, T., Schriefers, H., Baayen, R.H., Grainger, J., & Zwitserlood, P. (2008). Native language influences on word recognition in a second language: A mega-study, *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34* (1), 12-31. doi: 10.1037/0278-7393.34.1.12

Marian, V., Bartolotti, J., Chabal, S., & Shook, A. (2012). CLEARPOND: Cross-Linguistic Easy-Access Resource for Phonological and Orthographic

Neighborhood Density. *PLoS ONE, 7*(8): e43230. doi: 10.1371/journal.pone.0043230

Marian, V., Blumenfeld, H. K., & Kaushanskaya, M. (2007). The Language Experience and Proficiency Questionnaire (LEAP-Q): Assessing language profiles in bilinguals and multilinguals. *Journal of Speech, Language and Hearing Research, 50*(4), 940.

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: Part 1. An account of basic findings. *Psychological Review, 88*(5), 375-407.

Midgley, K. J., Holcomb, P. J., JB van Heuven, W., & Grainger, J. (2008). An electrophysiological investigation of cross-language effects of orthographic neighborhood. *Brain Research, 1246*, 123-135. doi: 10.1016/j.brainres.2008.09.078

Oldfield, R.C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia*, *9*, 97-113. doi: 10.1016/0028-3932(71)90067-4

Perea, M. (1998). Orthographic neighbours are not all equal: Evidence using an identification technique. *Language and Cognitive Processes, 13*(1), 77-90.

Perea, M., & Rosa, E. (2000). The effects of orthographic neighborhood in reading and laboratory word identification tasks: A review. *Psicológica, 21*(3), 327-340.

Van Hell, J. G., & Tokowicz, N. (2010). Event-related brain potentials and second language learning: Syntactic processing in late L2 learners at different L2 proficiency levels. *Second Language Research, 26* (1), 43-74. doi: 10.1177/0267658309337637 van Heuven, W. J., Dijkstra, T., & Grainger, J. (1998). Orthographic neighborhood effects in bilingual word recognition. *Journal of Memory and Language, 39*(3), 458-483.

TABLES

Table 1

Summary of Participants' Characteristics (Means and SDs Included)

	Age	Handedness	Highest education level	Age of acquisition (English)	Age of acquisition (Spanish)
Late Bilinguals (*n* = 26, 20 females)	20.88 (range 18-33, *SD* = 3.34)	24 right-handed, 1left-handed, 1 ambidextrous	26 Some college	0 (*SD* = 0)	12.54 (*SD* = 1.88)
Early Bilinguals (*n* = 30, 23 females)	20.07 (range 18-37, *SD* = 4.00)	26 right-handed, 3 left-handed, 1 ambidextrous	30 Some college	2.33 (*SD* = 2.20)	0 (*SD* = 0)

Table 2

Frequencies of Perceived Proficiency Questions on LEAP-Q for Early Bilinguals

	Speaking English	Understanding Spoken English	Reading English	Speaking Spanish	Understanding Spoken Spanish	Reading Spanish
None (0)	0	0	0	0	0	0
Very Low (1)	0	0	0	0	0	0
Low (2)	0	0	0	0	0	0
Fair (3)	0	0	0	0	1	1
Slightly Less Than Adequate (4)	0	0	0	0	0	1
Adequate (5)	1	0	0	1	0	0
Slightly More than Adequate (6)	1	0	0	1	0	3
Good (7)	0	1	3	10	0	8
Very Good (8)	7	1	5	8	10	11
Excellent (9)	8	7	7	7	10	4
Perfect (10)	13	21	15	3	9	2

Table 3

Frequencies of Perceived Proficiency Questions on LEAP-Q for Late Bilinguals

	Speaking English	Understanding Spoken English	Reading English	Speaking Spanish	Understanding Spoken Spanish	Reading Spanish
None (0)	0	0	0	0	0	0
Very Low (1)	0	0	0	0	0	0
Low (2)	0	0	0	0	0	0
Fair (3)	0	0	0	2	0	0
Slightly Less Than Adequate (4)	1	0	0	0	1	1
Adequate (5)	0	1	1	2	2	3
Slightly More than Adequate (6)	0	0	0	1	0	1
Good (7)	0	0	1	15	9	9
Very Good (8)	1	0	0	4	10	7
Excellent (9)	4	4	5	2	4	5
Perfect (10)	20	21	19	0	0	0

Table 4

Means and Standard Deviations of Stimuli Groups

Stimuli Groups	Length	Frequency	CLND	WLND	BF
English (high CLND)	5.20 (.62)	49.54 (142.93)	2.70 (1.08)	.90 (.72)	35.36 (21.04)
English (low CLND)	5.20 (.52)	45.79 (121.32)	.00 (.00)	.90 (.72)	33.04 (24.95)
Spanish (high CLND)	5.05 (.69)	41.90 (47.78)	2.85 (1.42)	.80 (.77)	31.38 (26.83)
Spanish (high CLND)	5.25 (.55)	72.43 (100.71)	.00 (.00)	.80 (.77)	32.61 (20.99)

Table 5

Error Responses for High CLND English Words for Early Bilinguals

English (High CLND)	Errors	Frequency of errors	Total Errors Per Word
ALLY		0	0
ARENA		0	0
BURDEN	Burben	1	2
	Burned	1	
CANVAS		0	0
CELLAR	Celiar	1	3
	Celler	1	
	Clear	1	
CREEP	Greed	1	1
CRIB	Grab	1	1
FELLA	Felia	2	3
	Spead	1	
FIERY	Fierry	1	3
	Fiary	1	
	Firy	1	
GRAVY	Gravity	1	1
LEERY	Lerry	5	8
	Leary	1	
	Liery	1	
	Every	1	
LIABLE	Label	1	3
	Libes	1	
	Lable	1	
LISTEN		0	0
POSSE	Posee	3	4
	Pose	1	
PRESS		0	0
QUITE	Quit	4	8
	Quiet	4	
RASCAL	Rasqal	1	2
	Rassch	1	
ROGUE	Rouge	4	5
	Trogue	1	
SUGAR		0	0
VALET	Vallet	2	2

Table 6

Error Responses for Low CLND English Words for Early Bilinguals

English (low CLND)	Errors	Frequency of errors	Total Errors Per Word
BELIEF	Beleif	1	3
	Belif	1	
	Ballet	1	
BLESS	Bliss	3	3
DUTY		0	0
EVERY	Ecery	1	1
FILTH	Filthy	1	3
	Fish	1	
	Flit	1	
GHOST		0	0
GROOVE	Grove	1	3
	Move	1	
	Groov	1	
HEIST	Hesit	2	2
KNEEL		0	0
NOTCH	Touch	1	1
QUICK	Qucik	1	1
RANSOM	Random	2	2
SEARCH	Serach	1	1
SKULL	Skul	1	2
	Skull\	1	
SMASH		0	0
SPIDER		0	0
SPREE	Spare	1	1
	Speer	1	1
SYRUP	Sryup	1	1
THIGH	Thing	1	1
WAIST	Wait	1	1
	Wasit	2	2
	Waiste	1	1

Table 7

Error Responses for High CLND Spanish Words for Early Bilinguals

Spanish (High CLND)	Errors	Frequency of errors	Total Errors Per Word
BOSQUE		0	0
CARNE	Garne	1	1
COLGAR		0	0
CRIAR	Ciar	1	5
	Critar	1	
	Crijar	1	
	Gritar	1	
	Granar	1	
DOLER	Dolor	2	3
	Dolcer	1	
DULCE		0	0
FIAR	Fair	1	3
	Fijar	1	
	Freir	1	
HUIR	Luir	1	1
JOVEN		0	0
LATIR	Lata	1	1
LLOVER	ilover	1	4
	Llora	1	
	Liover	1	
	Lover	1	
LUCIR	Lugar	1	4
	Lucer	2	
	Lucar	1	
MORDER	Moder	1	4
	Mujer	1	
	Morir	1	
	Morrer	1	
NENE	Nenee	1	1
NIVEL	Nieve	1	2
	Nive	1	
NUBE		0	0
PAPEL		0	0
PONER		0	0
RENDIR	-	1	10
	Render	8	
	Prendir	1	
RUMBO	Prumbo	1	1

Table 8

Error Responses for Low CLND Spanish Words for Early Bilinguals

Spanish (Low CLND)	Errors	Frequency of errors	Total Errors Per Word
ABAJO		0	0
ABEJA	Abuela	4	7
	Argeja	1	
	Abula	1	
	Abuja	1	
AMBAS	Amatar	1	3
	Ambasa	1	
	Ambisa	1	
AZUL		0	0
BOLSA	Bolsar	1	1
BONITA		0	0
CABEZA		0	0
FOGATA	Fota	1	3
	Fotgara	1	
	Bogata	1	
FUEGO	Luego	1	1
GUAPA	Culpa	1	2
	Guap	1	
JUEZA	Juevez	1	1
OREJA	Orega	1	3
	Orjea	1	
	Ojera	1	
PALCO	Palico	1	2
	Placo	1	
PEDIR	Perder	3	4
	Peder	1	
RELOJ	Rojo	1	4
	Relo	1	
	Relouj	1	
	Reljo	1	
SOMBRA	Mujer	1	2
	Somba	1	
TRINEO	Truino	1	9
	Trino	1	
	Trigo	1	
	Trieno	3	
	Triendo	1	
	Treino	1	
	Trieon	1	
VEJEZ	Veze	1	3

	Vejuz	1	
	Vejar	1	
VENIR	Vender	1	1
VESTIR	Vester	1	2
	Vestor	1	

Table 9

Error Responses for High CLND English Words for Late Bilinguals

English (High CLND)	Errors	Frequency of errors	Total Errors Per Word
ALLY	Alley	2	2
ARENA		0	0
BURDEN		0	0
CANVAS		0	0
CELLAR		0	0
CREEP	Creepy	1	1
CRIB	Grab	1	1
FELLA	Felia	4	4
FIERY	Every	1	1
GRAVY	Grave	1	1
LEERY	Leary	1	3
	Lerry	2	
	Leedy	1	
LIABLE	Lible	1	4
	Label	3	
LISTEN	Listen\	1	1
POSSE	Pose	2	2
PRESS		0	0
QUITE		0	0
RASCAL	Passer	1	3
	Racial	1	
	Pascal	1	
ROGUE	Rouge	3	4
	Progue	1	
SUGAR		0	0
VALET	Vallet	1	1

Table 10

Error Responses for Low CLND English Words for Late Bilinguals

English (low CLND)	Errors	Frequency of errors	Total Errors Per Word
BELIEF	Better	1	3
	Believe	1	
	Beleif	1	
BLESS	Bles	1	1
DUTY	Suty	1	2
	Dity	1	
EVERY		0	0
FILTH	Fith	1	1
GHOST	-	1	1
GROOVE		0	0
HEIST	Hesit	1	1
KNEEL	Knee	2	3
	Knead	1	
NOTCH		0	0
QUICK		0	0
RANSOM		0	0
SEARCH		0	0
SKULL	Skul	1	1
SMASH		0	0
SPIDER		0	0
SPREE	Sprite	1	1
SYRUP	Syurp	1	1
THIGH		0	0
WAIST		0	0

Table 11

Error Responses for High CLND Spanish Words for Late Bilinguals

Spanish (High CLND)	Errors	Frequency of errors	Total Errors Per Word
BOSQUE	Busque	1	1
CARNE		0	0
COLGAR	Golgar	1	2
	Colger	1	
CRIAR	Crair	2	6
	Griar	2	
	Craer	1	
	Crizar	1	
DOLER	Dolor	1	1
DULCE		0	0
FIAR	Ejar	1	2
	Saber	1	
HUIR	Hur	1	1
JOVEN		0	0
LATIR	Later	4	5
	Lejos	1	
LLOVER	Llorar	1	1
LUCIR	Lucer	1	1
MORDER	Moder	1	1
NENE	Rene	1	1
NIVEL		0	0
NUBE		0	0
PAPEL		0	0
PONER		0	0
RENDIR	Render	5	6
	Prender	1	
RUMBO		0	0

Table 12

Error Responses for Low CLND Spanish Words for Late Bilinguals

Spanish (Low CLND)	Errors	Frequency of errors	Total Errors Per Word
ABAJO	Amor	1	1
ABEJA	Abuela	3	4
	Abaja	1	
	Abueja	1	
AMBAS		0	0
AZUL		0	0
BOLSA		0	0
BONITA		0	0
CABEZA	Gabeza	1	1
FOGATA	Fortgar	1	2
	Bogata	1	
FUEGO		0	0
GUAPA	Gupa	2	3
	Cupa	1	
JUEZA	Jeuza	1	1
OREJA		0	0
PALCO		0	0
PEDIR	Peder	2	2
RELOJ	Rejol	1	2
	Reloy	1	
SOMBRA	Sobra	1	1
TRINEO	Trieno	3	5
	Treno	1	
	Tierno	1	
VEJEZ		0	0
VENIR		0	0
VESTIR		0	0

Table 13

Translation Error Examples

Type of Error	Example	Description of Error
Semantic	Providing "Mulo," meaning "Mule" in English, for "Thigh," which is "Muslo" in Spanish	Translations that differ in meaning from the actual translation
Morphological	Providing "Bendición," meaning "Blessing" in English, for "Bless," which is "Bendicir" in Spanish	Translations that use an incorrect morpheme and thus create a different word
Phonetic	Providing "Sheep" instead of "Bee" for "Abeja." Sheep is "Oveja," which is transcribed /o.ˈβe.xa/; Abeja is transcribed:/aˈβe.xa/	Translations to words that sound similar to the word in the language from which one is translating
Orthographic	Providing "Asucar" instead of "Azúcar" for "Sugar"	Translations that are misspelled by more than one letter
No Response		When an individual leaves a translation blank
Language Interference	Providing "Responsible" for "Liable," when the Spanish translation should be "Responsable"	Translations that are spelled in the language from which one is translating

Table 14

Summary of Monolingual Participants' Characteristics (Means and SDs Included)

	Age	Handedness	Highest education level
Monolinguals (*n* = 24, 20 females)	21.96 (range 19-40, *SD* = 4.20)	21 right-handed, 3 left-handed	24 Some college

Table 15

Error Responses for High CLND English Words for Monolinguals

English (High CLND)	Errors	Frequency of errors	Total Errors Per Word
ALLY	Alley	2	2
ARENA	Area	3	3
BURDEN	Barden	1	2
	Bueden	1	
CANVAS		0	0
CELLAR	Chair	1	3
	Gellar	1	
	Caller	1	
CREEP		0	0
CRIB	Grab	2	3
	Gib	1	
FELLA	Felia	3	4
	Fallen	1	
FIERY	Firey	1	1
GRAVY		0	0
LEERY	Lucky	1	6
	Lerry	2	
	Lerky	1	
	Lery	1	
	Lerey	1	
LIABLE	Label	2	2
LISTEN	Listen\	1	1
POSSE	Pose	3	3
PRESS		0	0
QUITE	Quiet	3	3
RASCAL	Pascal	1	1
ROGUE	Rouge	3	3
SUGAR		0	0
VALET	Valent	1	1

Table 16

Error Responses for Low CLND English Words for Monolinguals

English (Low CLND)	Errors	Frequency of errors	Total Errors Per Word
BELIEF	Believe	2	3
	Bullet	1	
BLESS		0	0
DUTY		0	0
EVERY		0	0
FILTH	Fith	1	3
	First	1	
	Flith	1	
GHOST		0	0
GROOVE		0	0
HEIST		0	0
KNEEL	Knee	1	2
	Knell	1	
NOTCH		0	0
QUICK		0	0
RANSOM		0	0
SEARCH		0	0
SKULL		0	0
SMASH	Shash	1	1
SPIDER		0	0
SPREE	Apree	1	2
	Speed	1	
SYRUP		0	0
THIGH		0	0
WAIST		0	0

Table 17

Error Responses for High CLND Spanish Words for Monolinguals

Spanish (High CLND)	Errors	Frequency of errors	Total Errors Per Word
BOSQUE		0	0
CARNE	Crair	1	3
	Garne	2	
COLGAR	Coligar	1	2
	Colgur	1	
CRIAR	Craier	1	5
	Griar	2	
	Ciara	1	
	Crair	1	
DOLER	Dolar	1	2
	Doller	1	
DULCE		0	0
FIAR	Fazir	1	2
	Firar	1	
HUIR	Her	1	1
JOVEN	Joben	1	1
LATIR	Later	7	7
LLOVER	Livor	1	1
LUCIR	Luger	1	5
	Lucer	3	
	Lucier	1	
MORDER	Moder	2	3
	Modor	1	
NENE		0	0
NIVEL	Nivek	1	2
	Nievel	1	
NUBE	Nubee	1	1
PAPEL		0	0
PONER		0	0
RENDIR	Render	6	9
	Rednir	1	
	Pender	1	
	Rener	1	
RUMBO	Usted	1	1

Table 18

Error Responses for Low CLND Spanish Words for Monolinguals

Spanish (Low CLND)	Errors	Frequency of errors	Total Errors Per Word
ABAJO	Abajto	1	1
ABEJA	Abejea	1	2
	Abueja	2	
AMBAS	Zambas	1	2
	Ambasa	1	
AZUL		0	
BOLSA	Bolesa	1	2
	Bolsaa	1	
BONITA	Brutta	1	3
	Bonta	1	
	Bontia	1	
CABEZA	Cabelza	1	5
	Cabasa	1	
	Gabeza	3	
FOGATA	Fogota	1	3
	Fogeta	1	
	Tofega	1	
FUEGO	Fuegp	1	1
GUAPA	Guara	1	2
	Grupa	1	
JUEZA	Juena	1	2
	Juezza	1	
OREJA	Orueja	1	1
PALCO	Placo	2	2
PEDIR	Perir	1	4
	Peder	2	
	Pedar	1	
RELOJ	Reluj	1	6
	Relou	1	
	Reljo	1	
	Rejo	1	
	Rejouj	1	
	Rejoul	1	
SOMBRA	Somga	1	1
TRINEO	Trieno	4	6
	Trienio	1	
	Trento	1	
VEJEZ	Vuejas	1	2
	Vejeze	1	
VENIR	Vener	2	2
VESTIR	Vester	4	7

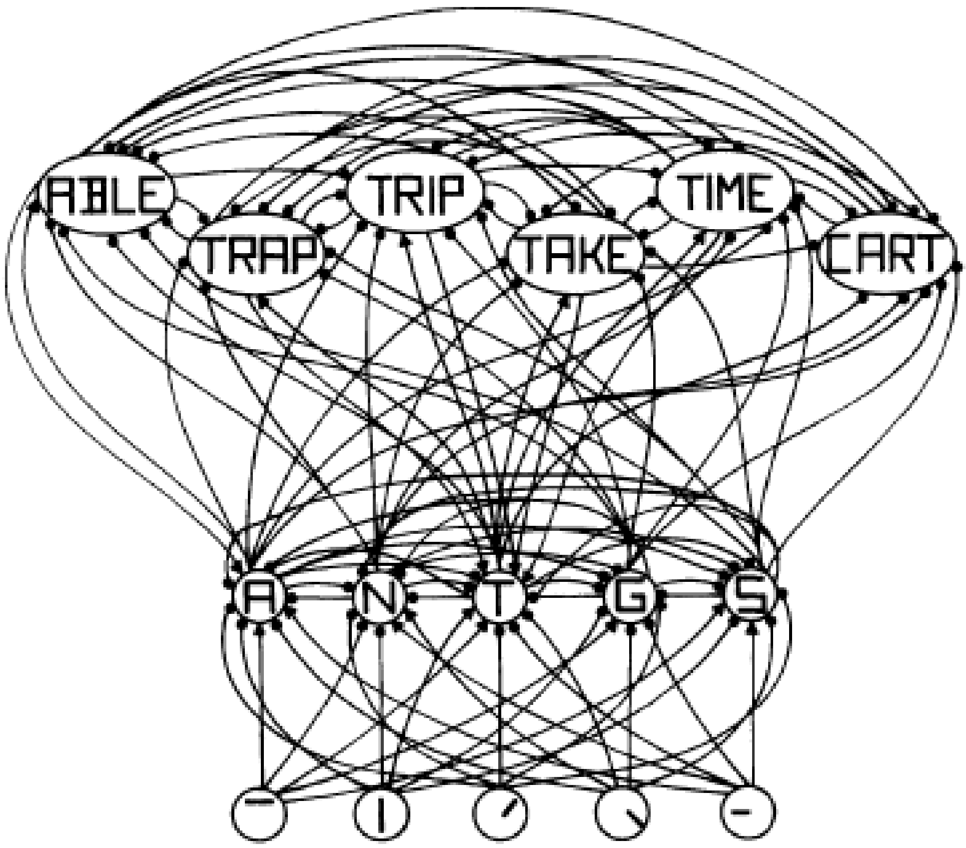

Figure 3. A few of the neighbors of the node for the letter *T* in the first position in a word, and their interconnections.

Figure 1. An example of how the IA model works from McClelland and Rumelhart (1981, p. 380).

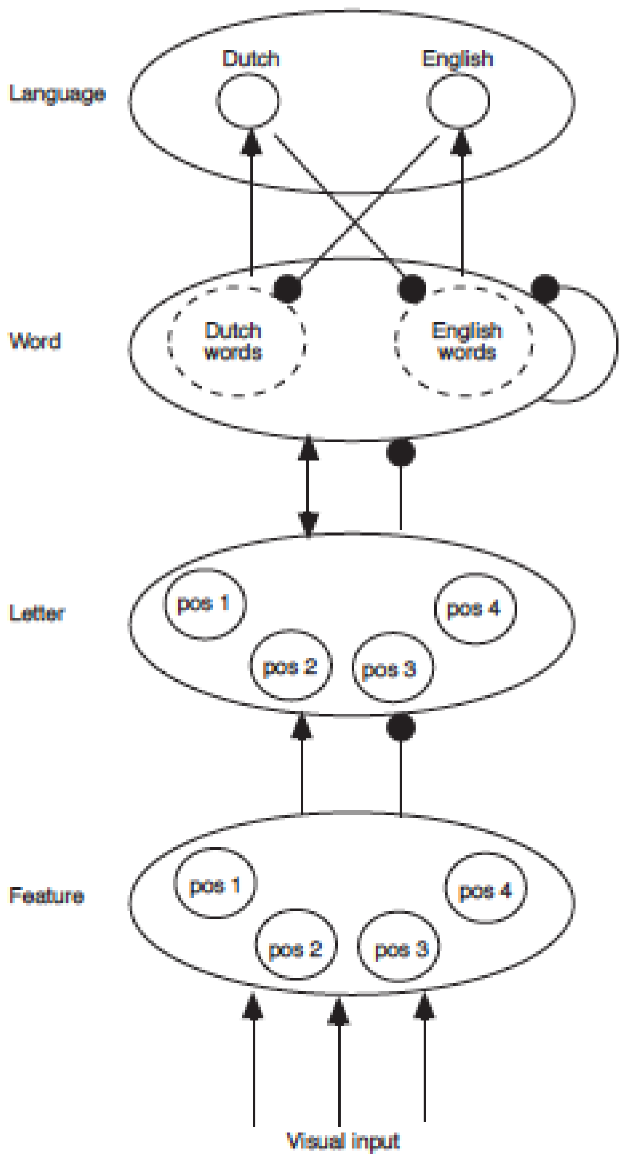

Figure 1. The Bilingual Interactive Activation (BIA) model for bilingual word recognition. Arrowheads indicate excitatory connections; black filled circles indicate inhibitory connections.

Figure 2. The BIA model from Dijkstra and van Heuven (2002a, p.177).

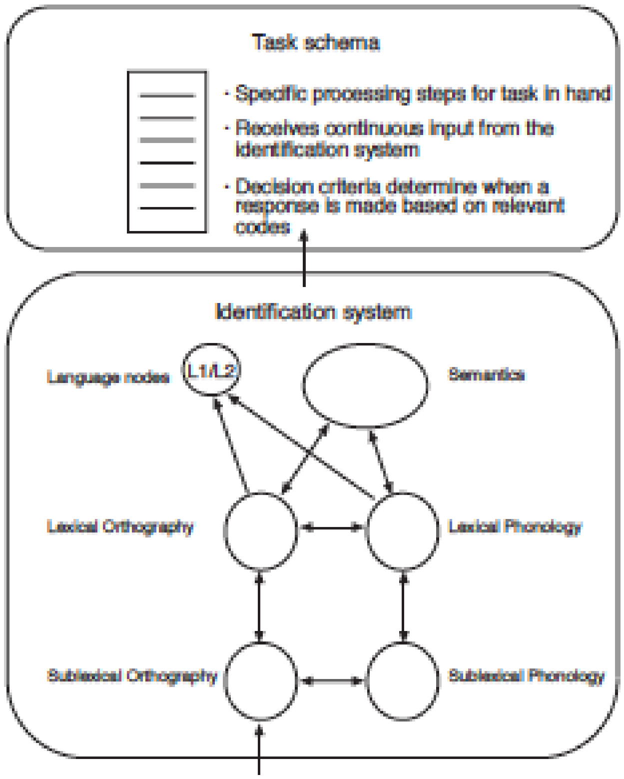

Figure 2. The BIA+ model for bilingual word recognition. Arrows indicate activation flows between representational pools. Inhibitory connections within pools are omitted. Language nodes could instead be attached to lemma representations between word form and meaning representations. Non-linguistic context only affects the task schema level.

Figure 3. The BIA+ model from Dijkstra and van Heuven (2002a, p. 182).

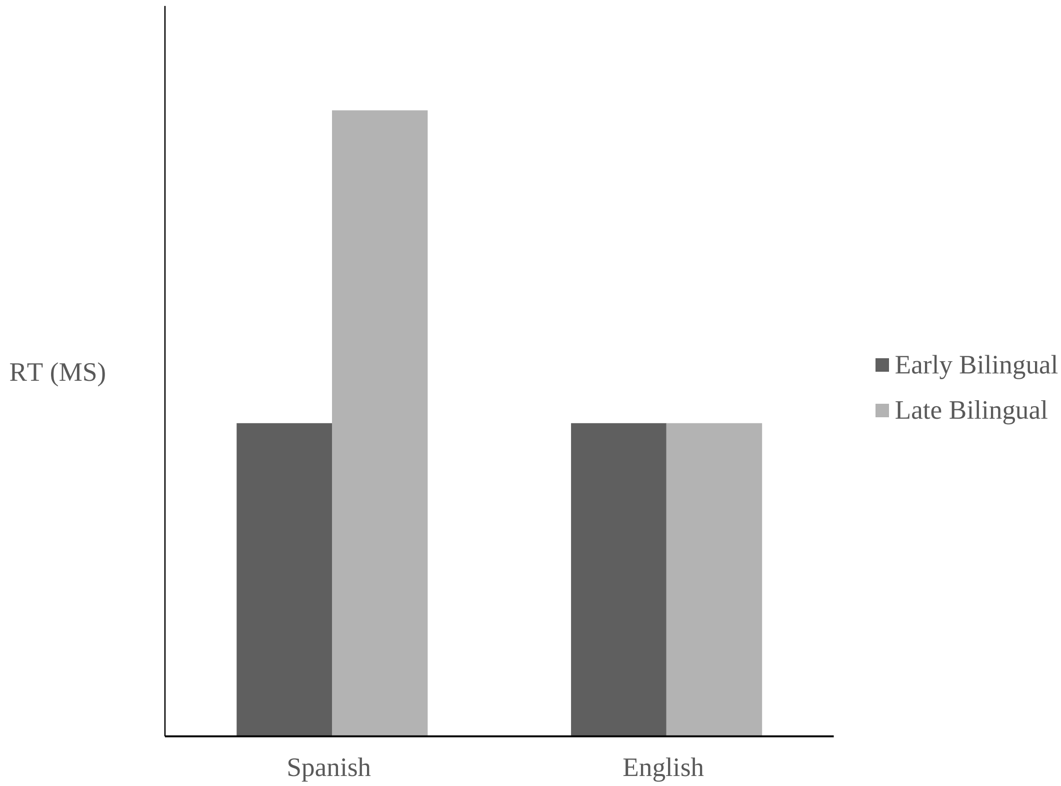

Figure 4. Group x Language Interaction Prediction

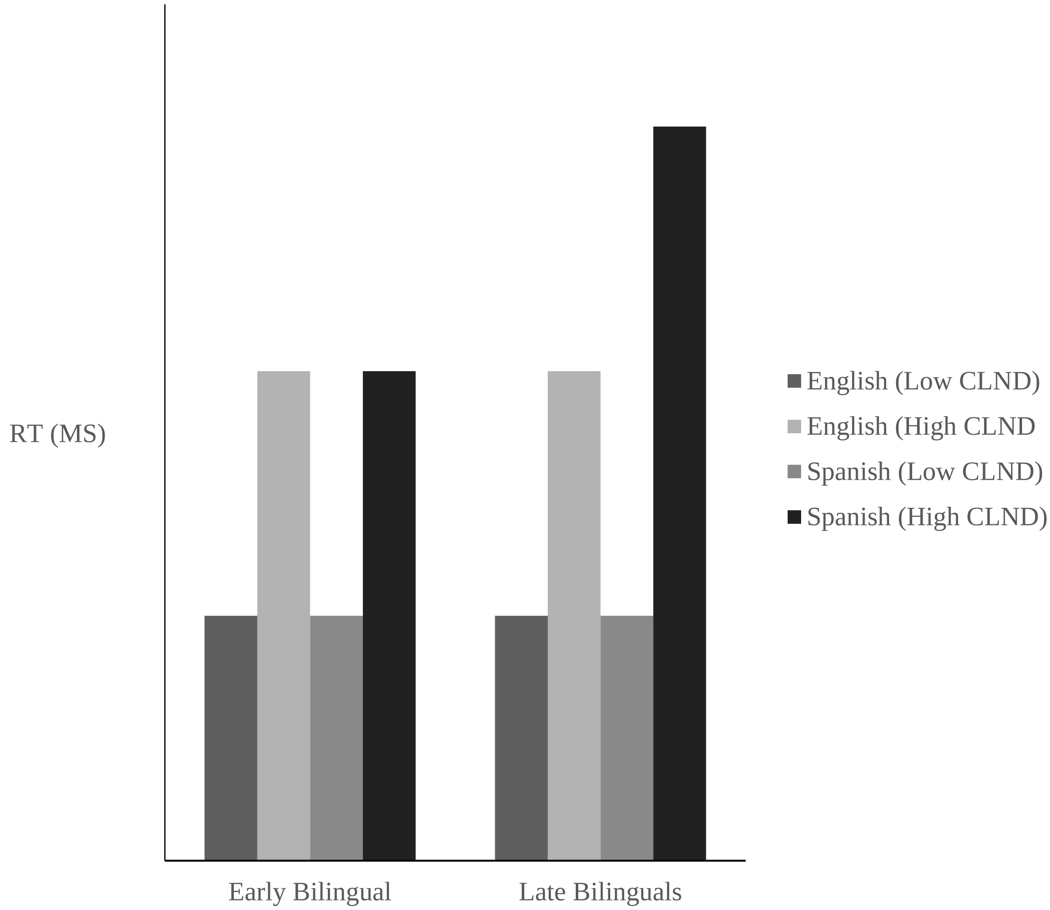

Figure 5. Language x CLND x Group Interaction Prediction

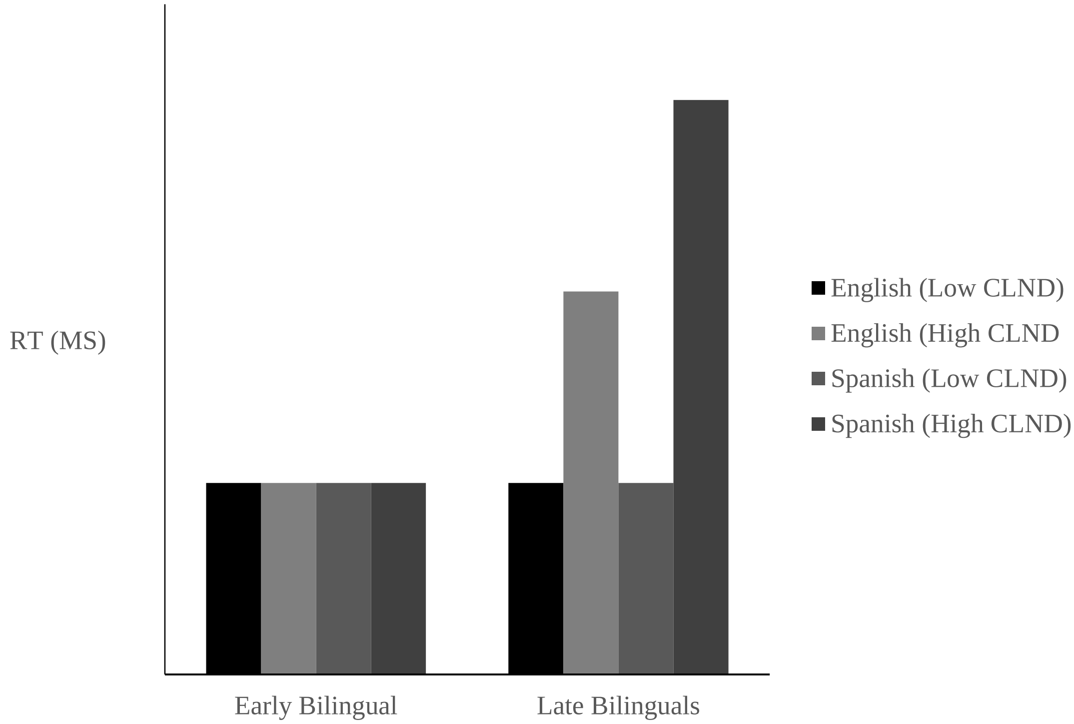

Figure 6. Alternate Language x CLND x Group Interaction Prediction

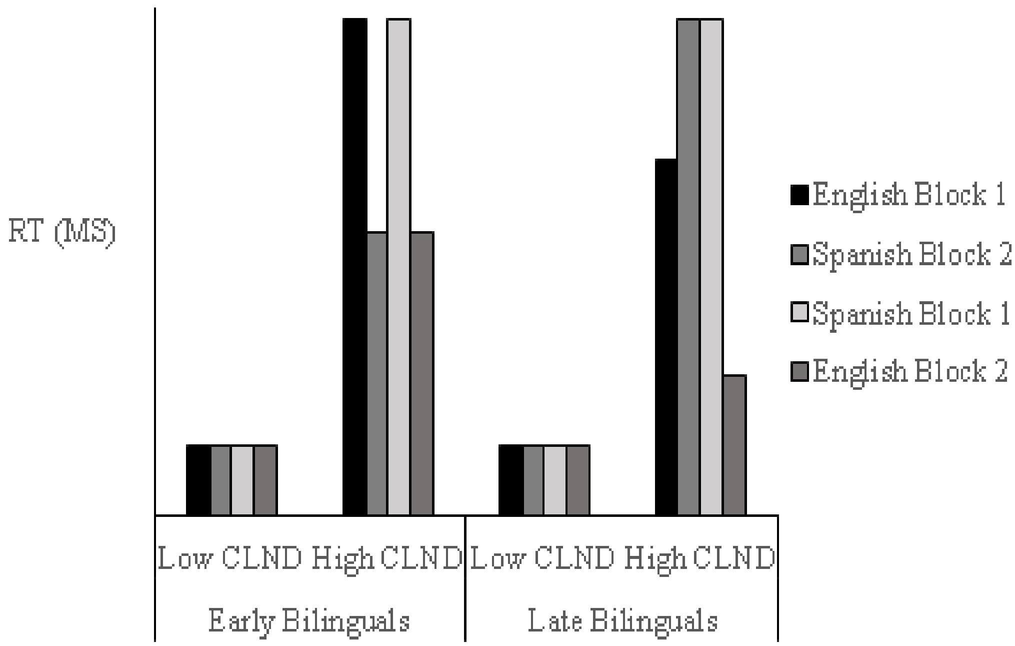

Figure 7. Group x Order x Language x CLND Interaction Prediction

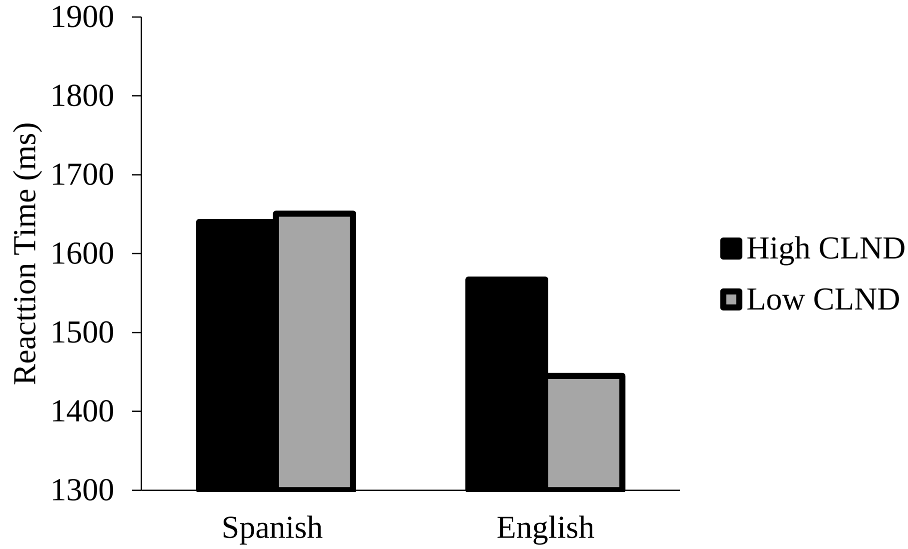

Figure 8. Reaction Time Results for Bilinguals: Language x CLND Interaction

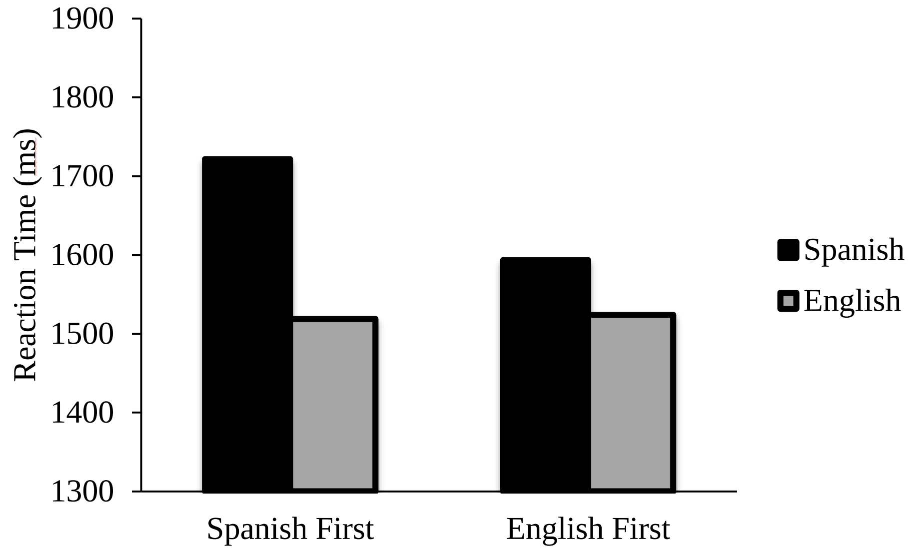

Figure 9. Reaction Time Results for Bilinguals: Order x Language Interaction

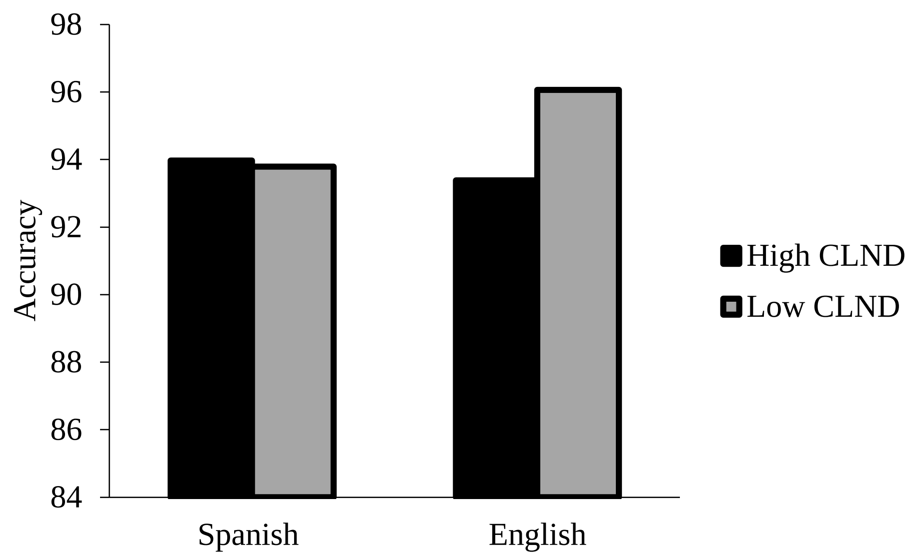

Figure 10. Accuracy Results for Bilinguals: Language x CLND Interaction

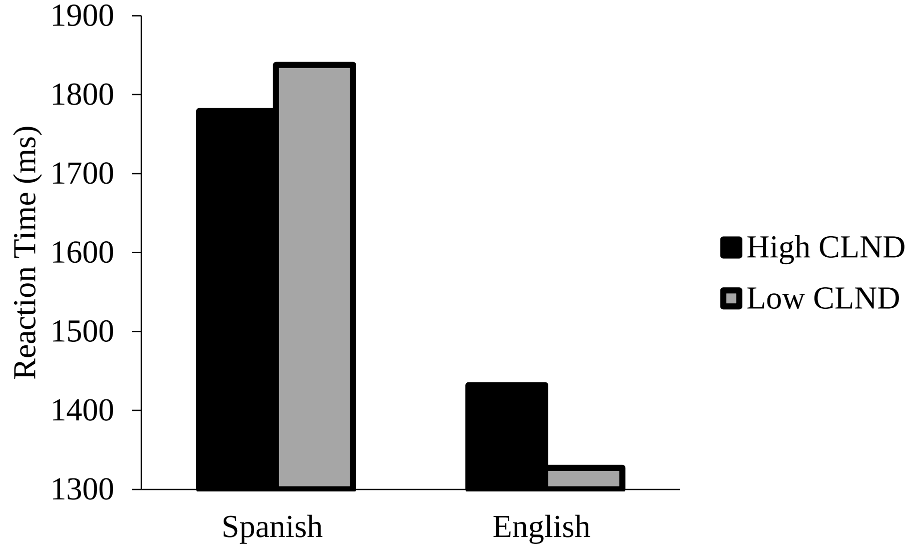

Figure 11. Reaction Time Results for Monolinguals: Language x CLND Interaction

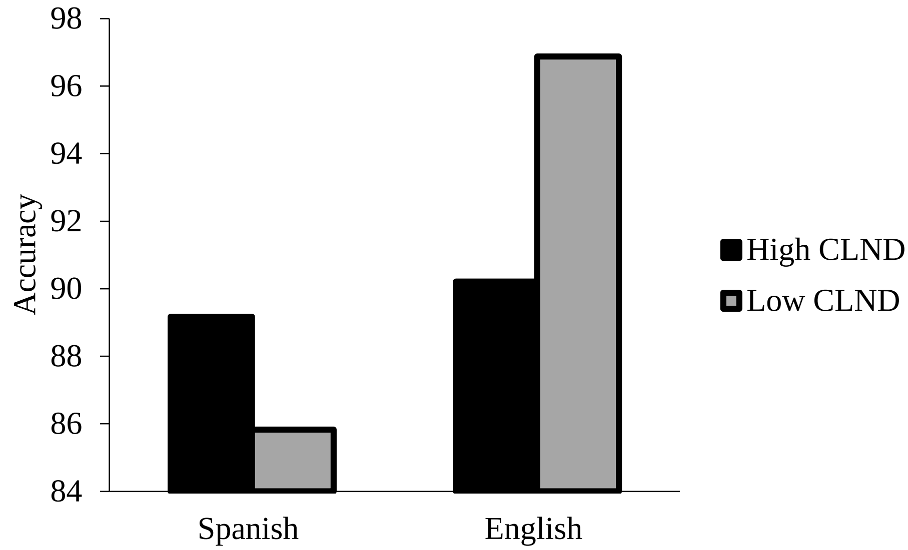

Figure 12. Accuracy Results for Monolinguals: Language x CLND Interaction

APPENDICES

Appendix A

Stimulus List

English (high CLND)	English (low CLND)	Spanish (high CLND)	Spanish (low CLND)
ALLY	BELIEF	BOSQUE (Wood)	ABAJO (Down)
ARENA	BLESS	CARNE (Meat)	ABEJA (Bee)
BURDEN	DUTY	COLGAR (To Hang)	AMBAS (Both)
CANVAS	EVERY	CRIAR (To Raise)	AZUL (Blue)
CELLAR	FILTH	DOLER (To Hurt)	BOLSA (Bag)
CREEP	GHOST	DULCE (Sweet)	BONITA (Beautiful)
CRIB	GROOVE	FIAR (To Sell on Credit)	CABEZA (Head)
FELLA	HEIST	HUIR (To Flee)	FOGATA (Campfire)
FIERY	KNEEL	JOVEN (Young)	FUEGO (Fire)
GRAVY	NOTCH	LATIR (To Beat)	GUAPA (Attractive)
LEERY	QUICK	LLOVER (To Rain)	JUEZA (Judge)
LIABLE	RANSOM	LUCIR (To Wear)	OREJA (Ear)
LISTEN	SEARCH	MORDER (To Bite)	PALCO (Gallery)
POSSE	SKULL	NENE (Small Child)	PEDIR (To Ask)
PRESS	SMASH	NIVEL (Level)	RELOJ (Watch)
QUITE	SPIDER	NUBE (Cloud)	SOMBRA (Shade)
RASCAL	SPREE	PAPEL (Paper)	TRINEO (Sled)
ROGUE	SYRUP	PONER (To Put)	VEJEZ (Old Age)
SUGAR	THIGH	RENDIR (To Perform)	VENIR (To Arrive)
VALET	WAIST	RUMBO (Direction)	VESTIR (To Dress)

Appendix B

Practice Stimuli

English	Spanish
ABOUT	AQUEL
AFTER	DESDE
AGAIN	ESTOY
AHEAD	IRNOS
COULD	LEJOS
FIRST	MIEDO
GUESS	MORIR
KNOWN	MUJER
MAYBE	NARIZ
SORRY	NOVIO
THEIR	NUNCA
WHICH	SALIR

Appendix C

Language Experience and Proficiency Questionnaire (p. 1 of 2)

Last Name		First Name		Today's Date	
Age		Date of Birth		Male ☐	Female ☐

(1) Please list all the languages you know in order of dominance:

1 Language A	2 Language B	3 Language C	4 Language D	5 Language E

(2) Please list all the languages you know **in order of acquisition** (your native language first):

1 Language A	2 Language B	3 Language C	4 Language D	5 Language E

(3) Please list what percentage of the time you are *currently* and *on average* exposed to each language.
(*Your percentages should add up to 100%*):

List language here:	Language A	Language B	Language C	Language D	Language E
List percentage here:					

(4) When choosing to read a text available in all your languages, in what percentage of cases would you choose to read it in each of your languages? Assume that the original was written in another language, which is unknown to you.
(*Your percentages should add up to 100%*):

List language here	Language A	Language B	Language C	Language D	Language E
List percentage here:					

(5) When choosing a language to speak with a person who is equally fluent in all your languages, what percentage of time would you choose to speak each language? Please report percent of total time.
(*Your percentages should add up to 100%*):

List language here	Language A	Language B	Language C	Language D	Language E
List percentage here:					

(6) Please name the cultures with which you identify. On a scale from zero to ten, please rate the extent to which you identify with each culture. (Examples of possible cultures include US-American, Chinese, Jewish-Orthodox, etc.):

List cultures here	Culture A (click here for scale)	Culture B (click here for scale)	Culture C (click here for scale)	Culture D (click here for scale)	Culture E (click here for scale)

(7) How many years of formal education do you have? ______________________________
Please check your highest education level (or the approximate U.S. equivalent to a degree obtained in another country):

☐ Less than High School
☐ High School
☐ Professional Training
☐ Some College
☐ College
☐ Some Graduate
☐ Masters
☐ PhD/MD/JD
☐ Other:

(8) Date of immigration to the United States, if applicable: ______________________________
If you have ever lived in another country, please provide name of country and dates of residence:
____

(9) Have you ever had a vision problem ☐, hearing impairment ☐, language disability ☐, or learning disability ☐? (Check all applicable).
If yes, please explain (including any corrections): ______________________________

Language Experience and Proficiency Questionnaire (p. 2 of 2)

Language: Language X

This is my (please select from scroll-down menu: First, Second, Third, etc.) language.
All questions below refer to your knowledge of Language X.

(1) Age when you...:

began acquiring Language X:	*became fluent* in Language X:	*began reading* in Language X:	*became fluent reading* in Language X:

(2) Please list the number of years and months you spent in each language environment:

	Years	Months
A country where Language X is spoken		
A family where Language X is spoken		
A school and/or working environment where Language X is spoken		

(3) On a scale from zero to ten, please select your *level of proficiency* in speaking, understanding, and reading Language X from the scroll-down menus:

Speaking	(click here for scale)	Understand spoken language	(click here for scale)	Reading	(click here for scale)

(4) On a scale from zero to ten, please select how much the following factors contributed to you learning Language X:

Interacting with friends	(click here for scale)	Language tapes/self instruction	(click here for scale)
Interacting with family	(click here for scale)	Watching TV	(click here for scale)
Reading	(click here for scale)	Listening to the radio	(click here for scale)

(5) Please rate to what extent you are currently exposed to Language X in the following contexts:

Interacting with friends	(click here for scale)	Listening to radio/music	(click here for scale)
Interacting with family	(click here for scale)	Reading	(click here for scale)
Watching TV	(click here for scale)	Language-lab/self-instruction	(click here for scale)

(6) In your perception, how much of a foreign accent do you have in Language X?
(click here for scale)

(7) Please rate how frequently others identify you as a non-native speaker based on your accent in Language X:
(click here for scale)

Appendix D

Demographics Questionnaire

PARTICIPANT INFORMATION SHEET

Subject Code: ____________ Gender F __ M __ O__ How old are you?

Is English the first language you learned? (please circle your choice) YES NO

What other languages do you know, if any, and when did you learn them? ____________________

Are you fluent in these other languages? YES NO

EDINBURGH ASSESSMENT OF HANDEDNESS

Please indicate your preferences in the use of hands in the following activities by **putting a +** in the appropriate column. Where the preference is so strong that you would never try to use the other hand unless absolutely forced to, **put ++.** If in any case you are really indifferent **put + in both columns.**

Some of the activities require both hands. In these cases, the part of the task or object for which hand-preference is wanted is indicated in parentheses.

Please try to answer all the questions, and only leave a blank if you have no expertise at all of the object or task.

	R	L		R	L
Writing			Tennis racket		
Drawing			Golf club		
Throwing			Broom (lower hand)		
Scissors			Rake (upper hand)		
Comb			Striking match (match)		
Toothbrush			Opening box (lid)		
Knife (without fork)			Dealing cards (card being dealt)		
Spoon			Threading needles (whichever is moved)		
Hammer			Which foot do you prefer to kick with?		
Screwdriver			Which eye do you use when using only one?		

Please circle your answer:

Do you consider yourself: RIGHT-HANDED LEFT-HANDED AMBIDEXTROUS

Is there anyone in your family (blood relative) who is left-handed? YES NO

If yes, what relation is this person to you? ____

Did you ever change your handedness? YES NO

If yes, when, and why? ____

Is there any activity not in this list for which you consistently use your non-dominant hand?

YES NO If yes, please list: ____

Have you ever experienced reading problems as a child? YES NO