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COGNITIVE CONTROL IN LINGUISTIC AND NON-LINGUISTIC CONTEXTS

IN BILINGUALS AND MONOLINGUALS

A Thesis in

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ABSTRACT

Research on bilingual language processing shows that bilinguals always have their two languages active, even in situations that require the use of only one language. So how do bilinguals successfully perform in one language without the other language intruding, and how do bilinguals seamlessly switch between their two languages when required? What control mechanism can explain how a bilingual manages to select what language they are speaking in? Is this mechanism specific to the practiced domain of language or does it also extend to more general, non-linguistic tasks requiring cognitive control?

The present study examines the cognitive correlates employed by bilinguals and monolinguals in both linguistic and non-linguistic contexts, and provides further insight into psycholinguistic models, such as the Inhibitory Control model (Green, 1998). Given that bilinguals have a unique experience with cognitive control as a result of managing the pervasive parallel activation of their two languages, I investigate whether bilinguals and monolinguals recruit the same cognitive mechanisms in linguistic and non-linguistic contexts.

Cognitive control in linguistic and non-linguistic contexts is examined in English-Spanish bilinguals, Spanish-English bilinguals, and English monolinguals. Bilinguals and monolinguals are presented with interlingual and intralingual homographs and controls in a language-specific (English) lexical decision task and in a generalized lexical decision task (linguistic context) and complete a non-verbal task switching task (non-linguistic context). In the English lexical decision task, bilinguals tested in their first language recognized interlingual homographs more quickly than matched controls, whereas bilinguals tested in their second language did not recognize interlingual homographs differently than the matched controls. Meanwhile, both groups of bilinguals and the monolinguals recognized intralingual homographs more quickly than matched the controls. In the generalized lexical decision task, only the Spanish-English bilinguals recognized interlingual homographs differently than the matched controls. In particular, Spanish-English bilinguals recognized these homographs more quickly than the controls. Moreover, both bilingual groups recognized intralingual homographs more quickly than the matched controls. In the cued color-shape task, bilinguals and monolinguals experienced a switch cost, where participants were slower and less accurate to respond to switch trials as compared to non-switch trials. The magnitude of the switch cost was not different for bilinguals and monolinguals.

Response latency data from the lexical decision tasks suggest that lexical ambiguity within and across languages does not require suppression of one lexical candidate. Instead, it appears that a speaker is able to respond as soon as a homograph's representations are recognized and before an alternate lexical candidate is considered, eliminating semantic competition from occurring. Moreover, this study complements recent behavioral studies that have begun to examine how the role of executive control in linguistic tasks relates to bilingual performance in non-linguistic tasks by investigating differences between bilinguals and monolinguals in their use of executive control in linguistic and non-linguistic contexts. In particular, the findings from this study suggest that bilinguals do not differ from monolinguals in how they employ cognitive control in linguistic contexts. Moreover, it appears that bilinguals' practice with executive control in linguistic tasks does not extend to their performance on non-linguistic tasks, because both bilinguals and monolinguals experience switch costs, where they respond less quickly and less accurate to switch trials as compared to non-switch trials, and the magnitude of these switch costs were not different.

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Chapter 1

Introduction

A key finding in research on bilingual language processing is that bilinguals always have their two languages active, even in situations that require the use of only one language. Remarkably, even though both languages are active simultaneously, bilinguals rarely commit errors of intrusion from their other language. So how is it that bilinguals successfully perform in one language without intrusions from the other language, and also seamlessly switch between their two languages when required, given ubiquitous evidence for pervasive parallel activation of both languages (e.g., Dijkstra, 2005; Kroll, Bobb, Misra, & Guo, 2008; Van Hell & Tanner, 2012)? What control mechanism can explain a bilingual's ability to juggle their languages? Is this cognitive control mechanism specific to the practiced domain of language or is it domain-general, and does it extend to non-linguistic tasks requiring cognitive control? The overarching aim of the present study is to test whether and how bilingual speakers utilize general cognitive mechanisms in linguistic and non-linguistic contexts alike. A secondary goal is to answer whether these mechanisms vary with knowledge of a second language. That is, do monolinguals and bilinguals behave similarly in response to conflict in linguistic and non-linguistic contexts?

In the following section, I will first introduce language non-selective and language-selective views on lexical access. This theoretical review includes the discussion of two theoretical models, a word recognition model which describes the processes thought to occur after lexical access and a word production model which has been adapted to explain word comprehension. Afterward, I will present psycholinguistic research on visual word processing that discusses how a bilingual speaker's relative language proficiencies and even the stimuli being tested may interact with language selectivity and how a monolingual speaker resolves lexical ambiguity from within their one language. I will then review behavioral non-linguistic studies on inhibitory control that have examined if the same form of control observable in linguistic processing (i.e., word processing) is used in non-linguistic tasks. Specifically, I will focus on studies examining conflict resolution in visual perception.

Theories on language non-selectivity (this is a Heading 2 style)

A key question in the past decades of research on bilingual lexical processing is whether lexical access is selective or non-selective with respect to language. The language-selective view argues that lexical access is limited to the language in use, whereas the language non-selective view states that lexical access it not limited to only the language in use. Many studies testing the language-selective versus the language non-selective lexical access theories have compared the processing of language ambiguous and language non-ambiguous words. Two types of language ambiguous words that have commonly been studied are cognates and homographs (e.g., De Groot, Delmaar, & Lupker, 2000; Dijkstra, Timmermans, & Schriefers, 2000; Dijkstra, Miwa, Brummelhuis, Suppelli, & Baayen, 2010; Elston-Guttler, Gunter, & Kotz, 2005; Von Studnitz & Green, 2002). Cognates are words that share semantics, orthography, and phonology across languages (e.g., ‘chocolate’ in English and Spanish). Homographs are words that share orthography and phonology, but always differ in their semantics (e.g., ‘pie’ in English means ‘foot’ in Spanish). The overarching finding is that language ambiguous words (cognates, homographs) are processed differently than language unambiguous words. This finding is interpreted as evidence for language non-selective access.

Bilingual Interactive Activation Plus Model for visual word recognition (this is a Heading 3 style)

Dijkstra and Van Heuven (2002) proposed the Bilingual Interactive Activation Plus (BIA+ Model) to explain how orthography, phonology, and semantics are activated in bilingual word recognition. The BIA+ model is adapted from the Interactive Activation Model (McClelland & Rumelhart, 1981), which was designed to account for monolingual word recognition and reading. The BIA+ model consists of two systems: the word identification system and the task/decision system (see Figure 1-1).

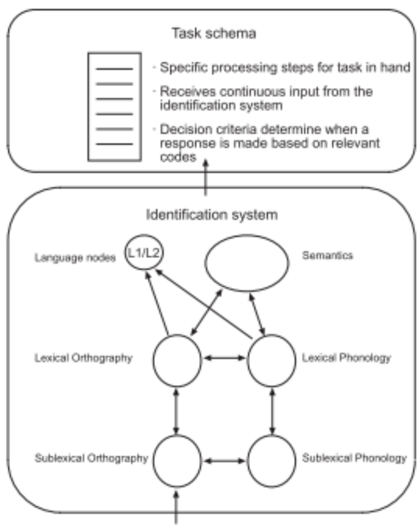

Figure **1-1**: The BIA+ Model for word recognition (Dijkstra & Van Heuven, 2002).

As the name suggests, the word identification system handles linguistic input. The model assumes language non-selectivity in that there is a shared integrated lexicon in which words from both languages are stored and accessed together. As a result, upon visual presentation of a word, the individual letter features, or sub-lexical features, and related candidates from both of a bilingual's languages are activated. For example, upon presentation of the word 'lamp', anything that starts with the letter 'l' in either of a bilingual's languages is also activated. Activation of the sub-lexical graphemes then spreads to sub-lexical phonemes. Once the word identification system has recognized these features, activation spreads to all related orthographic and phonological codes that align with what was identified at the sub-lexical level. The information activated then feeds into the semantic codes and the language nodes.

Activation within the word identification system begins with information that feeds into the system co-activating all codes that are similar, while inhibition suppresses the less similar of the candidates. There are bidirectional links between orthographical, phonological, and semantic codes, but unidirectional orthographical and phonological links at the lexical level leading information to the language nodes. As a result of these links, language identification is a purely bottom-up process. Thus, the model predicts that language of the word (or of the context) cannot be used as a cue to help with the word identification process.

The second part of the model, the task/decision system, incorporates Green's ideas on task schemas and task control (Green, 1998; see description below). The task/decision system receives linguistic input from the word identification system and triggers a response if the criteria established by task demands are fulfilled. Specifically, this system is responsible for task-specific codes reaching the activation threshold according to task demands in order for the relevant cues to receive more directed attention. For example, in a generalized lexical decision task, a bilingual participant is asked to decide whether a letter string forms a word or a non-word across their two languages. The BIA+ model proposes that the task/decision system is responsible for processing the letter string's codes to discriminate the string at a word/non-word level. On the other hand, in a language-specific lexical decision task, a bilingual participant is asked to decide whether a letter string forms a word or a non-word in one of their languages. In this scenario, the BIA+ model proposes that the task/decision system is responsible for restricting the set of orthographic codes that are processed during word recognition to the target language. As a result, this system ensures efficient behavioral performance on a given task with respect to both speed and accuracy.

Crucially, the BIA+ model is able to make clear predictions for how words with cross-language overlap will be recognized. The model predicts for cognates to be processed more quickly than non-cognate controls (cognate facilitation). The processing difference is caused by the overlap in orthographic, phonological, and semantic codes of cognates and the resulting strong language co-activation. On the other hand, the model predicts for homographs to be processed more slowly than non-cognate controls (homograph interference), with the discrepancy in semantics resulting in conflict. Specifically, the co-activation of different meanings across languages results in competing semantic codes, such that upon presentation of a homograph there will be slowed processing times as compared to non-homographs.

Inhibitory Control Model

The Inhibitory Control (IC) Model (Green, 1998), which explains the management of a bilingual's two languages, was initially proposed to explain language production. However, the model has been adopted to explain bilingual language comprehension, too. Like other explanations of the bilingual lexico-semantic control system, this particular model assumes that candidates from both languages are activated and are competing for selection. Specifically, the IC model proposes that for successful performance in the second language, a bilingual employs a general cognitive mechanism, inhibitory control, to actively inhibit their first language.

The IC Model is based on a model that was originally created to explain the involvement of action of control in routine versus non-routine behaviors (Norman & Shallice, 1986). Like the original model, the IC model consists of the supervisory attentional system (SAS) and task schemas (see Figure 1-2). The SAS affects the level of activation in task schemas to ensure successful task performance. In turn, language-specific task schemas are responsible for regulating the output from the lexico-semantic system by raising activation for the representation in the intended language and suppressing the competing activated candidates from the non-target language. Task schemas are able to organize themselves into circuits and function at the lemma level.

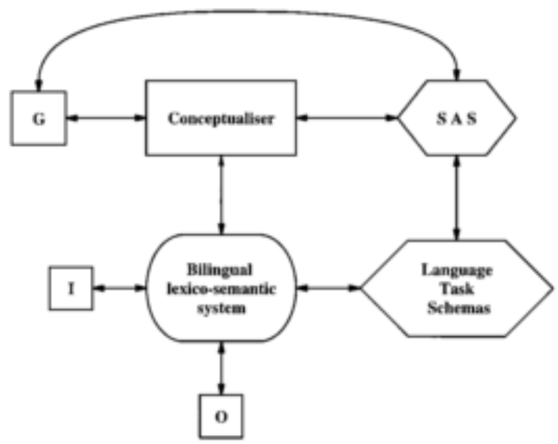

Figure **1-2**: The levels of control in the Inhibitory Control Model (Green, 1998).

Green states that for lexical selection to be successful, lemma (candidates) must first be specified in terms of "language tag". Each lemma is then marked as either belonging to a bilingual's first or second language. In turn, this tag affects the amount of activation the lemma receives and demarcates which ones should be suppressed from the output system.
However, it is not the case that once a lemma is tagged with membership from the non-target language that it can no longer interfere with lexical selection. Instead, the amount of inhibition required to suppress a given word is hypothesized to vary according to its level of activation. Accordingly, it is hypothesized that there is a relationship between language proficiency and the amount of inhibition needed for successful language production. In general, this model predicts that more inhibition is needed to suppress words from the first language when second language production is intended. Moreover, this prediction manifests itself in an asymmetric switching cost in which reaction times are exaggerated when a bilingual speaker goes from using their second

language to their first language, which was previously heavily suppressed from interfering with task performance.

Empirical studies on language-selective versus non-selective activation

In an early study on lexical access in cognate and homograph processing, Gerard and Scarborough (1989) manipulated word frequency in order to determine whether lexical information is represented in separate language-specific lexicons. According to the language-selective view—in which lexical access is limited to the language being used— the time it takes to process a given word will depend primarily on the frequency of that word in the target language. As such, words with varying frequencies in the non-target language should not show variation when being processed in the target language. For example, since the word "red" has a high frequency in English and a low frequency in Spanish, it should be processed in English as quickly as other high frequency English words, despite its relatively low frequency in Spanish, and it should be processed in Spanish as quickly as other lower-frequency Spanish words. Alternatively, according to the language non-selective view — in which lexical access is not limited to the language in use— the time it takes to process a given word should depend on the frequency of that word across languages. As a result, homographs that have a high frequency in the target language and a low frequency in the non-target language should be processed as quickly as high frequency language non-ambiguous words in both the target language and the non-target language.

In the second half of their experiment, Gerard and Scarborough examined whether early encoding processes prior to lexical accesses are language-selective or non-selective. In particular, although separate lexicons might be accessed, it is possible that the encoding processes in the word recognition process are separate or shared. They examined these encoding processes by presenting stimuli for a second time. Crucially, the stimuli now appeared in the context of the bilingual's other language. Given that repeated exposure to a word results in faster processing, Gerard and Scarborough were able to investigate which types of words (e.g., cognates, homographs, or controls) experienced facilitation and whether cross-language transfer effects were based on orthography, semantics, or a combination of the two. The language-selective view predicts that processing times will depend on the frequency of a word in the target language. However, it also posits that homographs and cognates that are presented a second time will receive a boost in lexical access. On the other hand, while the language non-selective view also predicts facilitation, it specifically predicts that facilitation will be modulated by overlap in orthographic and semantic representation. In general, the non-selective view predicts that cognates, homographs, and control words presented a second time will be processed more quickly than when they are presented the first time, with cognates benefiting the most from the repetition because of their shared orthographic and semantic representations.

Spanish-English bilinguals and English monolinguals completed two lexical decision tasks. In the first lexical decision task, half of the bilinguals were asked to decide by pushing one of two buttons whether the letter strings formed words in the first language (Spanish). The other bilinguals were asked to decide whether the letter strings formed words in their second language (English). All of the monolinguals were asked to decide whether letter strings formed English words. Stimuli consisted of English-Spanish cognates, English-Spanish homographs, and a set of control words. For the bilinguals, the control words were language non-ambiguous Spanish words. For the monolinguals, the control words were the English translations of the Spanish controls. In the second lexical decision task, the target language changed for the bilinguals, such that the bilinguals who had previously been instructed to respond according to their first language (Spanish) were now asked to respond according to their second language (English) and vice versa. The same set of cognate and homograph stimuli was presented for a second time. However, now the bilinguals with Spanish as the target language saw English control words and the bilinguals with English as the target language saw Spanish control words. The monolinguals performed the same task as before and the same set of stimuli was presented for a second time.

In the first lexical decision task, the bilinguals and monolinguals in the English context processed the low frequency cognates, homographs, and controls more slowly than the high frequency words (cognates, homographs, and controls), demonstrating a within-language frequency effect. Furthermore, both bilingual and monolingual participants processed low frequency homographs significantly more slowly than the low frequency cognates and control words. There were no significant differences in processing times for the high-frequency cognates, homographs, or control words. Thus, when asked to make lexical decisions in their second language, bilinguals functioned similarly to monolinguals. The bilinguals in the Spanish context processed low frequency cognates significantly faster than low frequency control words, exhibiting a cognate facilitation effect. There was no significant difference in how they processed low frequency homographs as compared to control words. Moreover, there were no significant differences in processing times for the high frequency cognates, homographs, or control words. Gerard and Scarborough interpreted the findings from the first lexical decision task as support for the language-selective view. The homograph's frequency in the target language predicted processing times for the bilinguals in the first and second language and bilinguals were seemingly not influenced by their knowledge of non-target representations of the critical words.

In the second lexical decision task, bilinguals identified letter strings according to a language different from the first task. Half of the bilinguals completed the task in their first language and the other half in their second language. Bilinguals again processed homographs according to their frequencies in the target languages; high frequency homographs were processed more quickly than the high frequency control words and low frequency homographs were processed more slowly than the low frequency control words. Despite the fact that all of the bilinguals performed this task in a different language than when they completed the first lexical decision task, cognates and homographs were actually processed more quickly than the first time they were first presented. Moreover, for bilinguals this repetition effect occurred independent of word frequency. In this second lexical decision task, the monolinguals also processed the stimuli that appeared for a second time more quickly than in the first lexical decision task. However, for monolinguals this effect was dependent on word frequency, with low frequency words benefitting the most from this repetition. Researchers interpreted the repetition effect (facilitation) found in the second experiment as evidence for shared encoding processes. Overall, despite the indications of cross-language activation and language non-selectivity, Gerard and Scarborough interpreted their data as being in favor of language-selective lexical access with shared encoding processes.

Although Gerard and Scarborough (1989) interpreted their findings to signify support of language selectivity, the majority of studies have supported the language non-selective view of lexical access. For example, Dijkstra, Van Jaarsveld, and Ten Brinke (1998) also tested lexical access by examining cognate and homograph processing. Specifically, they investigated two factors posited to influence lexical non-selectivity: the degree of cross-linguistic similarity of the stimuli and the type of task that the participants are asked to perform (Grosjean, 1997). Dijkstra and colleagues expected for processing times to be modulated as a degree of cross-linguistic similarity. In particular, because cognates overlap in semantics, orthography, and phonology, cognates would be processed more quickly than non-cognate controls. In contrast, homographs would be processed more slowly than non-homograph controls, because different semantics leads to competition between the homograph's two meanings, which would slow down lexical access. Moreover, researchers expected to observe stronger effects of language selectivity in tasks that require use of only one language as compared to tasks that require use of both languages.

Three groups of Dutch-English bilingual participants completed three different lexical decision tasks. In the first two experiments, bilinguals completed a language-specific lexical decision task in their second language, English (one of the two kinds of linguistic tasks that will be administered as part of the proposed study). In Experiment 1, participants were asked to decide whether letter strings were English words by pushing one of two buttons. The stimulus set featured Dutch-English interlingual homographs of varying frequencies, Dutch-English cognates, English control words, and English non-words. In Experiment 2, participants were also asked to decide whether letter strings were English words by button press. However, in this experiment the English cognates were removed and replaced with Dutch monolingual filler words. In Experiment 3, participants completed a generalized lexical decision task (one of the two kinds of linguistic tasks that will be administered as part of the proposed study). In this task, participants were asked to decide whether letter strings were words in either Dutch or English by button press. The stimulus set was the same as that used in Experiment 2.

By administering language-specific and generalized lexical decision tasks, Dijkstra et al. (1998)'s data also help examine the idea of stimulus- and response-based conflict (see Figure 1-3). Stimulus-based conflict refers to the competition that occurs between the activated representations of a concept from a bilingual's two languages. Response-based conflict occurs when a participant is required to make a decision based on the activated representations.

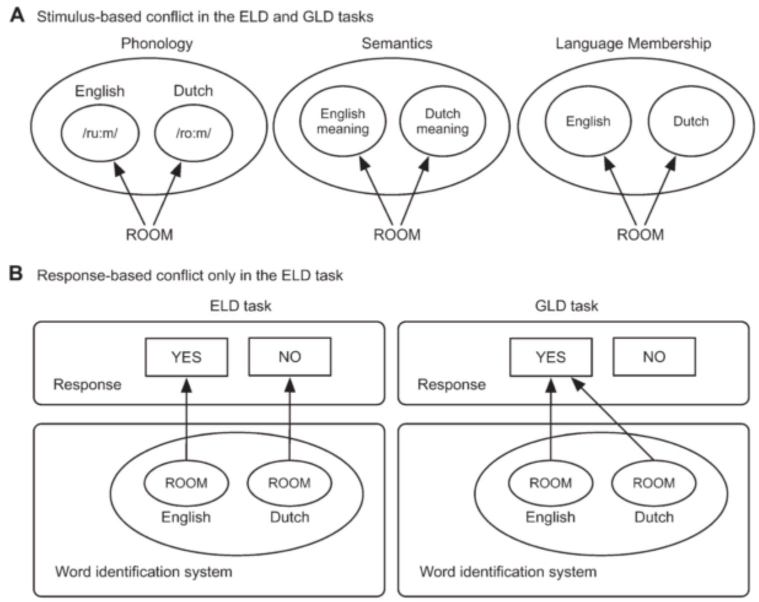

Figure **1-3**: Stimulus- and response-based conflict (Van Heuven et al., 2008).

Behaviorally, response-based conflict is predicted to occur only when a bilingual completes language-specific lexical decision tasks. Here, a homograph's two meanings would compete for selection up through the decision-making phase, because bilinguals have to identify the letter string in the context of a particular language before responding, as well as inhibit the competing homograph's meaning from the non-target language. It is predicted that bilinguals require additional processing time in order to resolve this response-based conflict. Meanwhile, both the English and generalized lexical tasks are predicted to generate stimulus-based conflict, because each letter string activates competing semantic representations (and to a certain extent also phonological, and language membership representations) from the two languages. Thus, if the homograph effect is driven by response-based conflict, homographs will be processed slower than control words, but only in language-specific lexical decision tasks. On the other hand, if the homograph effect is driven by stimulus-based conflict, homographs will be processed as quickly as control words in both language-specific and generalized lexical decision tasks.

Response latency data across the generalized and language-specific lexical decision tasks confirmed the degree of language non-selectivity depends heavily on the demands of the task and the degree of cross-linguistic similarity in the stimuli. In the language-specific lexical decision task, latencies were faster for cognates than for control words, whereas latencies for homographs were no different than those for control words (Experiment 1). However, when English-Dutch cognates were removed and replaced with Dutch filler words (e.g., English non-words) in the language-specific lexical decision task (Experiment 2), the latencies were slower for homographs than for control words, supporting language non-selectivity. In the generalized lexical decision task (Experiment 3), latencies were faster for homographs than for control words.

The difference in response times for homographs relative to controls in the language-specific lexical decision task (Experiment 2) as compared to the generalized lexical decision task (Experiment 3) suggests that task instructions have an impact on how these words are processed. When the instructions require participants to consider the stimuli with respect to one, pre-specified language, there are exaggerated processing times for homographs as compared to non-homograph controls. However, when this language-specific constraint is removed, there are no longer exaggerated processing times for homographs as compared to non-homograph controls, rather homographs are processed more quickly than non-homograph controls. This pattern of latencies can be taken as evidence that homographs processed in a language-specific context results in response-based and stimulus-based conflict in the processing system. Specifically, in a language-specific context, the response-based conflict that the homographs pose on the processing system requires additional time to resolve. On the other hand, when homographs are processed in a language non-specific context, such as that created by the generalized lexical decision task, a homograph's two meanings no longer need to compete with each other for a response to be made. Task instructions are such that a response can be made once the letter string is identified as a word in either language. In a generalized context then, response-based conflict is eliminated, leaving only stimulus-based conflict. Thus, the response is being based on the availability of any meaning, irrespective of language, so that homographs can be processed as quickly, or more quickly, than non-homograph controls.

In sum, Dijkstra and colleagues argue that the differences in latencies demonstrate that the processing of homographs is affected by the amount of non-target language activation caused by the entire stimulus set and by task demands. These latencies can be taken as indirect evidence for bottom-up lexical activation, with the language of the stimulus set insufficient at overriding this bottom-up lexical activation. Furthermore, the finding that homographs were processed slower than controls in the English lexical decision task confirms that homograph processing in a language-specific context results in response- and stimulus-based conflict, where the response-based conflict requires additional time to resolve. Meanwhile, the finding that homographs were processed as quickly as controls in the generalized Dutch-English lexical decision task indicates that response-based conflict has been removed and that stimulus-based conflict does not require any additional processing time to resolve.

More recently, Brenders, Van Hell, and Dijkstra (2011) extended Dijkstra et al.'s (1998) finding that task demands affect language ambiguous word recognition to cognate processing. Brenders and colleagues employed a cross-sectional design in order examine whether word recognition in native Dutch children who were beginning and intermediate second language learners of English is comparable to word recognition in highly proficient adult Dutch-English bilinguals in terms of processing strategies. In Experiment 1, cognates were presented in an English (L2) lexical decision task. In Experiment 2, cognates were presented in a Dutch (L1) lexical decision task. In Experiment 3, cognates were presented alongside homographs in an English lexical decision task. No cognate facilitation was observed in the L1 lexical decision task (Experiment 2), which replicates findings from the adult bilingual literature. Meanwhile, cognate facilitation was observed in both groups of learners in L2 lexical decision task (Experiment 1).

Interestingly, in the presence of homographs, cognates (and homographs) were recognized less quickly than their respective controls (Experiment 3). The combined results from this study suggest that like homographs, processing of cognates is also affected by the amount of non-target language activation caused by the entire stimulus set, at least in beginning and intermediate L2 learners.

Lemhöfer and Dijkstra (2004) further investigated how task instructions modulate second language cognate and homograph processing in a series of four lexical decision tasks. Four groups of Dutch-English bilinguals completed four different lexical decision tasks. In Experiments 1 and 2, two groups of bilinguals completed two different English lexical decision tasks. Experiment 1 featured Dutch-English homographs, Dutch control words, and non-words that were created to resemble English words and non-words that were "neutral" with respect to language membership as stimuli. Experiment 2 featured Dutch-English cognates in place of homographs. In Experiments 3 and 4, two new groups of bilinguals completed two different generalized lexical decision tasks. Experiment 3 again featured the same stimuli as Experiment 1. However, Dutch-like non-words were added to the stimulus set in order preserve the "generalized" nature of the task. Experiment 4 featured the same set as Experiment 2, but it also contained added Dutch-like non-words. Thus, the design of Lemhöfer and Dijkstra's (2004) differed from that used in Dijkstra et al. (1998) in two ways. First, the cognate and homograph stimuli tested in Lemhöfer and Dijkstra (2004) were split into separate experiments. Second, the non-words were created to preserve the English and generalized nature of the experiments.

Interestingly, the response latency data from Lemhöfer and Dijkstra (2004) are not consistent with those in Dijkstra et al. (1998). In the L2 English lexical decision tasks, homographs (Experiment 1) and cognates (Experiment 2) were processed more quickly than control words. Meanwhile, English-like non-words were processed less quickly than neutral non-words. In the generalized lexical decision tasks, facilitation was observed again for both the homographs (Experiment 3) and cognates (Experiment 4). Moreover, the error rate data across these four tasks support the facilitation effect observed in the response latency data. The researchers explained these unique findings by stating that it is likely that the time courses for word recognition are different in a second-language versus generalized-language context. Specifically, in the English lexical decision task, the researchers hypothesized that homographs are facilitated by their orthographic overlap between languages, allowing them to be processed similarly to cognates. Meanwhile, in a generalized setting, the researchers hypothesized that a response can be made based off of the first representation that reaches activation. However, Lemhöfer and Dijkstra (2004) used a similar design as other studies (i.e., homographs presented in a language-specific lexical decision task in the L2) and this explanation cannot account for the homograph interference reported in these studies (e.g., Dijkstra et al., 1998; Van Heuven et al., 2008).

Van Heuven, Schriefers, Dijkstra and Hagoort (2008) also investigated cross-language ambiguity. They studied homograph processing using behavioral and functional magnetic resonance imaging methods in order to examine the loci of two forms of conflict: stimulus- and response-based conflict. As described previously, stimulus-based conflict is the competition between the activated representations of a concept from a bilingual's two languages, whereas response-based conflict occurs when a participant is required to make a decision based on the activated representations. Two groups of Dutch-English bilinguals and one group of English monolinguals completed the experiment. One group of Dutch-English bilinguals and the English monolinguals completed an English lexical decision task, and the other group of bilinguals completed a generalized Dutch-English lexical decision task.

Bilinguals were predicted to suffer from response- and stimulus-based conflict, with additional processing time required to resolve the response-based conflict in the English lexical decision task. The researchers hypothesized that the brain regions recruited to resolve stimulus-and response-based conflict would overlap with brain regions that have been implicated in executive control. In particular, increased neural activity of the anterior cingulate cortex (ACC) and the pre-supplementary motor area (pre-SMA) was predicted to mediate response-based conflict. Bilinguals were expected to show recruitment of these structures only in the English lexical decision task. Meanwhile, increased neural activity of the left inferior prefrontal cortex (LIPC) was predicted to mediate stimulus-based conflict. Bilinguals were expected to show recruitment of the LIPC in both the English and the generalized lexical decision task. Monolinguals were not predicted to suffer from response- or stimulus-based conflict and no processing time differences were expected for homographs as compared to matched controls. No differences in recruitment of neural correlates for homographs as compared to controls were predicted for monolinguals.

Indeed, bilinguals were significantly slower to respond to homographs than to English control words in the language-specific (English) lexical decision task. This finding reflects the predicted response-based conflict. However, there was no reaction time difference in the homographs and control words in the generalized lexical decision task. Their neuroimaging data differed for the different lexical decision tasks, too. In the language-specific (English) task, heightened activation was observed in regions of the LIPC, as well as in the pre-SMA and ACC. In the generalized task, neuroimaging data revealed heightened activation present in two specific clusters within the LIPC for homographs as compared to control words. These findings were interpreted to reflect the idea that elimination of response-based conflict by removal of language-specific task instructions also eliminates cross-language interference. As expected, there were no differences in the monolingual naming times or neural activation as a function of word type, which indicates that monolinguals were not sensitive to the interlingual homograph stimuli and confirms that the effects observed in the bilingual data were the result of cross-language activation.

Overall, Van Heuven et al. (2008) replicated the inhibitory effect for homograph processing from Dijkstra et al. (1998). When participants processed words in their second language (English), they took longer to process homographs as compared to English control words. However, it is important to remember that not all studies support this homograph inhibition effect (e.g., Lemhöfer & Dijkstra, 2004). Thus, it appears that homograph processing is modulated by several factors, such as the task instructions (language-specific vs. generalized) whether the stimulus list is comprised of stimuli related to one language or multiple languages.

De Groot, Delmaar, and Lupker (2000) extended the use of language-specific and generalized lexical decision tasks in order to examine homograph processing the first and second language. Four groups of Dutch-English speakers were assigned to four different language-specific lexical decision tasks. Experiments 1A and 1B were in Dutch and English, respectively. Critical words were homographs and non-homograph controls. The non-words used in the lexical decision task were all orthographically permissible letter strings in the target language. The non-words in the Dutch task never formed words in English and the non-words in the English task never formed words in Dutch. In Experiment 1A, the Dutch condition, homographs were processed more slowly as compared to non-homograph controls. However, in Experiment 1B, the English condition, homographs were processed no differently than non-homograph controls. This difference in findings is hard to reconcile with the non-selective access theory, which would propose that it is less likely for activation from the weaker language candidates (English) to reach a threshold where the weaker language could affect processing in the dominant language (Dutch). De Groot and colleagues hypothesized that this surprising finding suggests that participants were not following instructions and may have been treating the language-specific lexical decision task as a generalized lexical decision task. Furthermore, they argued that the choice of non-words in Experiments 1A and 1B increased the likelihood of participants using this strategy.

Following these unexpected results, De Groot and colleagues conducted a second set of experiments to test whether the participants in Experiments 1A and 1B were unconsciously approaching the task as a generalized lexical decision task. Experiments 2A and 2B were in Dutch and English, respectively. They differed from Experiments 1A and 1B in that half of the non-words were orthographically permissible letter strings in the target language and the other half were words from the non-target language functioning as non-words. Now, homographs from Experiments 2A and 2B were processed more slowly as compared to the non-homograph controls from Dutch and English, respectively. The authors conclude that the difference in processing times across experiments suggests that while the participants in Experiments 1A and 1B were indeed engaged in a "language neutral" processing mode when completing the tasks, a non-selective access view can explain the pattern of results obtained in the four experiments conducted.

In the present study, we will conduct a series of language-specific and generalized lexical decision tasks that will compare interlingual homograph processing to non-homograph controls in bilinguals. We will employ the same design used by De Groot et al. (2000), in which participants are presented with words in either their first (English; Experiment 1) or second (Spanish; Experiment 2) language. Recall that this is a significant difference from the design employed by Dijkstra et al. (1998), Lemhöfer and Dijkstra (2004), and Van Heuven et al. (2008), where participants completed language-specific lexical decision tasks limited to their second language. By doing so, we also are able to examine whether language non-selectivity occurs in the first language. In particular, we will be able to see if homograph processing in the first language results in competition as it has often been observed to do in the second language (Dijkstra et al., 1998; Van Heuven et al., 2008). However, our study features a methodological improvement over De Groot et al. (2000). English-Spanish and Spanish-English bilinguals will be recruited so that we can investigate first and second language homograph processing using the same stimuli. In addition to this difference, we will recruit bilinguals who are dominant specifically in their first language, so that we can examine how relative proficiency affects homograph processing, and language non-selectivity, more generally.

As a result of these changes we made to the study design, we expect to observe a unique set of findings that has not been reported before. We expect only for participants whose second language is English to experience response-based conflict in the English lexical decision task, because the second language (English) representations of the homographs will reach the activation threshold after the first language (Spanish) representations. In particular, we expect for Spanish-English bilinguals to experience homograph interference. We do not expect for participants whose first language is English to experience this same response-based conflict in the English lexical decision task. Instead, their first language (English) representations of the homographs will reach threshold more quickly than the second language representations, removing response-based conflict and the need for additional processing time. In particular, we do not expect for the English-Spanish bilinguals to experience homograph interference, but for there to be no difference in latencies for homographs as compared to controls. Meanwhile in the generalized lexical decision task we expect there to be no difference in latencies for homographs as compared to controls for both groups of bilinguals, because we have removed the language constraint.

Lexical ambiguity in monolingual processing

Outside of bilingual word recognition models and studies examining bilinguals processing homographs, lexical ambiguity has also been examined in monolingual contexts using intralingual homographs (e.g., Azuma & Van Orden, 1997; Borowsky & Masson, 1996). Intralingual homographs are words within a language that share orthographic and phonological representations, but differ in meaning (e.g., ‘chest’, which in English can refer to a part of the body or a storage container). Early research employing lexical decision tasks observed that intralingual homographs are processed more quickly than words with only one meaning, suggesting a facilitative effect on word recognition (e.g., Kawamoto, Farra, & Kello, 1994). However, more recent research has challenged this finding (e.g., Klepousniotou & Baum, 2007; Rodd, Gaskell, & Marslen-Wilson, 2002; 2004). Instead, it appears that word recognition times depend heavily on not only whether a word has more than one meaning, but also whether a word’s meanings are related or not.

Rodd, Gaskell, and Marslen-Wilson (2002) conducted a series of three lexical decision tasks. Three different groups of native English speakers participated in the study. Stimuli in the experiment included frequency-matched English intralingual homographs with related meanings (e.g., the word ‘twist’), English intralingual homographs with unrelated meanings (e.g., the word ‘bark’), and English words with only one meaning (e.g., the word ‘frog’). It appeared that intralingual homographs with unrelated meanings were recognized more slowly as compared to both intralingual homographs with related meanings and to words with only one meaning. According to frequency-based models, the time needed to recognize and decide whether a letter string forms a word in English would depend on the frequency of that given word. However, frequency-based models fail to account for the finding that processing times are modulated by meaning relatedness. Instead, processing time depends on the number of semantic representations that exists for a given word (whether the word is a homograph or not) and whether the semantic representations are related or unrelated. Indeed, word recognition models best explain facilitation and interference effects by positing competition between an intralingual homograph’s unrelated meanings and an advantage for homograph’s related meanings (Gaskell & Marslen-Wilson, 1997; Hinton & Shallice, 1991; Joordens & Besner, 1994; Plaut, 1997). In addition to the competition-based mechanism, a mechanism of facilitation may exist. In particular, co-activation between an interlingual homograph's unrelated lexical representations may produce homograph interference and a seemingly paradoxical advantage for intralingual homographs with related meanings.

In the present study, we will include an intralingual homograph manipulation to the English and generalized lexical decision tasks. In addition to the English-Spanish and Spanish-English bilinguals discussed earlier, we also will recruit English monolinguals to participate in this experiment. However, the English monolinguals will only complete the English lexical decision task. By including intralingual homographs and by testing English monolinguals, we are able to help answer a new question. Do speakers with the same first language resolve within-language lexical ambiguity in the same way regardless of language experience (English-Spanish bilinguals vs. English monolinguals)? Or, is it the case that language experience affects how within-language lexical ambiguity is resolved, causing English-Spanish and Spanish-English bilinguals to perform more similarly than English-Spanish bilinguals and English monolinguals? A secondary question we are able to provide insight on is whether within-language lexical ambiguity is resolved in the same manner when it occurs in the first versus the second language.

We expect only for participants whose first language is English to be sensitive intralingual homograph processing. In particular, we expect for English-Spanish bilinguals to experience increased facilitation if English monolinguals experience intralingual homograph facilitation. On the other hand, if English monolinguals experience homograph interference, then we expect for English-Spanish bilinguals to experience decreased interference. Given the mixed findings from previous studies, it is unclear whether participants will experience facilitation or interference. However, we expect for English-Spanish bilinguals to process intralingual homographs differently than English monolinguals as a result of being bilingual and experience resolving cross-language conflict. Meanwhile, we expect for Spanish-English bilinguals to demonstrate the same form of sensitivity to intralingual homographs only if they are similarly proficient in English as the native English participants. Otherwise, we expect for Spanish-English bilinguals to not experience either facilitation or interference. We expect to observe these effects in both the English and generalized lexical decision task, because the change in task instruction should not affect within-language co-activation.

General cognitive control and response selection and inhibition

The form of conflict described in the previous sections is not limited to language processing. Instead, similar conflict also exists in non-linguistic contexts. Given that the IC Model proposes that responds to linguistic conflict and works to resolve it, it is reasonable to assume that the same form of this mechanism is used during language processing and general cognition. Indeed, inhibition has long received attention for its implications on higher-order cognition. It has been proposed that the ability to suppress irrelevant information and ignore the desire to perform on inappropriate actions is the basis of how humans control their behavior. For example, response inhibition is active when we pay attention to one conversation over another or suppress emotions of frustration leading to any aggressive action. A deficit in this skill has been implicated in neuropsychiatric disorders such as attention deficit/hyperactivity disorder (Simmonds, Pekar, & Mostofsky, 2008).

In order to better understand the IC Model's proposed language control mechanism in light of general cognitive control, I will now discuss inhibition in the domain of general cognition in more detail. First, I will introduce a hypothesis that proposes that bilinguals demonstrate an advantage at cognitive control in non-linguistic tasks and briefly review research that has found evidence for this bilingual advantage. Afterward, I will discuss one study in depth that uses a non-linguistic task-switching paradigm in order to compare bilingual and monolingual cognitive control in non-linguistic tasks. This fMRI study will also serve as the basis of the non-linguistic task being administered in the present study.

Bilinguals performing non-linguistic tasks

Given a bilingual's experience managing the concurrent activation of their two languages, it is feasible that a bilingual has enhanced cognitive control that would be apparent in resolving non-linguistic conflict. Indeed, bilinguals are less affected by the conflict trials in a number of tasks, including the Simon and Flanker tasks (e.g., Bialystok, Craik, & Luk, 2008; Costa, Hernández, & Sebastián-Gallés, 2008). Bilinguals are overall more accurate and faster to respond in these conflict trials as compared to monolinguals. Although this advantage has not always been found in young adults (e.g., Bialystok, Martin, and Viswanathan, 2005) it has been observed in both bilingual children (e.g., Bialystok & Martin, 2004; Martin-Rhee & Bialystok, 2008; Poarch & Van Hell, 2012) and older adults (e.g., Bialystok, Craik, Klein, & Viswanathan, 2004; Bialystok, Craik, & Luk, 2008; Bialystok, Craik, & Ryan, 2006).

Garbin et al. (2010) investigated executive control (e.g., inhibition) in Spanish-Catalan early bilinguals and Spanish monolinguals as they completed a non-linguistic switching task in the MRI scanner. Specifically, using a single item cued color-shape task-switching paradigm, Garbin et al. presented participants with one stimulus at a time. The stimulus could be either a circle or square, and be red or blue. At the same time, an instructional linguistic cue would appear on the screen informing the participants whether they should respond according to color or shape. Participants were asked to respond by button press as quickly and accurately according to this cue.

Behaviorally, a significant effect of accuracy by trial type was reported with more accurate performance observed for non-switch trials than switch trials. This effect was modulated by a significant trial by group interaction. Interestingly, this interaction revealed that the bilinguals did not show a switching cost, indicating that it was mainly the monolingual group that drove the switch effect. A significant effect of response latency by trial type was also reported, again with faster response latencies observed for non-switch trials as compared to switch trials. Interestingly, it appears that the monolingual group was again driving a trial by group interaction, which was approaching significance. The fMRI data showed that for bilinguals as compared to monolinguals there was heightened activation lateralized to the left hemisphere in the IFG and striatum in response to switch trials, a pattern of activation consistent with the networks thought to underlie language control. In the monolingual participants, more activation was observed in the right inferior frontal gyrus (IFG) and the ACC in response to switch trials compared to non-switch trials. Interestingly, these data suggest that a switch in trial type affected the bilinguals less than the monolinguals and that the bilinguals relied on neural correlates also implicated in language control. Moreover, the fact that the bilinguals did not show a switching cost may be the result of task demands being too easy.

In the present study, we will conduct a modified version of the cued color-shape task employed by Garbin et al. (2010). English-Spanish bilinguals, Spanish-English monolinguals, and English monolinguals will complete the task. The linguistic instructional cues indicating whether participants should respond according to color or shape will be modified to symbols in order to make the task completely non-linguistic in nature. We will also shorten the inter-stimulus interval from what was used in the original article, because we will administer this task behaviorally rather than in an MRI scanner. By modifying the task and including these three speaker groups, we are able to investigate whether monolinguals and bilinguals resolve non-linguistic conflict similarly or differently. Moreover, we are able to examine how and whether conflict resolution in a linguistic context relates to conflict resolution in a non-linguistic context, making this study one of the first to ask this question within the same population of individuals rather than generalize results from different studies and different participant groups.

Based on the results from Garbin et al. (2010), we expect for bilinguals and monolinguals to experience a switch cost, such that we will observe increased response latencies and decreased accuracy for switch trials as compared to non-switch trials. Like Garbin et al. (2010), we expect for monolinguals to drive this effect. However, if enhanced bilingual control is the result of a more specific language experience than bilingualism, then it is possible for the English-Spanish and Spanish-English bilingual groups to differ in performance from each other.

Chapter 2

The present study

The present study examines the cognitive control mechanism in both linguistic and non-linguistic contexts in bilinguals and monolinguals, providing further insights into theoretical models, such as the Inhibitory Control model (Green, 1998). This study also complements the recent behavioral studies that have begun to examine how the role of executive control in linguistic tasks relates to bilingual performance in non-linguistic tasks.

Specifically, recent behavioral studies, comprised of task switching and language switching experiments, sought to answer whether experience with codeswitching, a bilingual language phenomenon in which a speaker switches effortlessly between their languages within the course of a conversation, influences executive functioning (e.g., Prior & MacWhinney, 2010; Prior & Gollan, 2011; Yim & Bialystok, 2012; Weissberger, Wierenga, Bondi, & Gollan, 2012). Task switching and language switching are thought to tap into the same underlying mechanisms for several reasons (Prior & MacWhinney, 2010). First, the two processes require task schema to be used so that a competing, incorrect response is not made (e.g., a response made according to the non-target instructional cue or using the non-target language). Second, switch cost asymmetries appear in both switching domains. In particular, switching from an easier task to a more a difficult task can result in a reduced switch cost. For example, Meuter and Allport (1999) observed a larger switching cost when switching into the dominant first language. The IC Model explains this finding as being the result of having to disengage inhibition of the first language, which is generally relied on for successful second language production. Thus, when switching from the second to the first language rather than have the advantage of performing a task in the dominant language, a bilingual speaker must first overcome a well practiced cognitive control mechanism. If codeswitching involves domain general executive functioning mechanisms similar to those used in language switching and task switching, then it is possible that frequent codeswitchers would confer an advantage at task switching.

Prior and MacWhinney (2010) examined whether lifelong bilingualism results in enhanced cognitive control in task switching. In particular, researchers were interested in learning whether bilinguals have reduced switching costs, mixing costs, or both as compared to monolinguals. Switching costs were defined as the classically reported difference in performance between switch and non-switch trials in mixed blocks. Mixing costs were defined as the difference in performance between pure blocks and the non-switch trials from the mixed blocks. Performance was measured in the form of response latencies and accuracy. Bilinguals who had learned English and another language before the age of six and native English monolinguals who had not studied or been exposed to another language participated in the experiment. Participants completed a battery of cognitive and linguistic measures, including a cued color-shape task similar to that used in Garbin et al. (2010). A reduced switching cost was observed for the bilinguals as compared to monolinguals, where bilinguals were able to respond more quickly after switch trials than monolinguals. Meanwhile, bilinguals and monolinguals alike experienced a mixing cost. Researchers interpreted these findings as support for enhanced cognitive control in bilinguals, specifically in situations that require switching between task schema.

Prior and Gollan (2011) examined whether a history of code-switching confers an advantage in language switching and task switching. Two groups of bilinguals and one group of English monolinguals participated in the experiment. In particular, Spanish-English bilinguals, who reported code-switching on a daily basis, and Mandarin-English bilinguals, who reported code-switching less often, were recruited. Participants completed a battery of cognitive and linguistic measures, including a non-linguistic task-switching task and a language-switching task (bilinguals only). The task-switching task chosen was similar to that used by Garbin et al. (2010)

and Prior & MacWhinney (2010). The language-switching task required participants to name the digits out loud in a pre-determined language depending on the instructional cue. If code-switching involves a domain general cognitive mechanism, then only the Spanish-English bilinguals should show an advantage as compared to the English monolinguals, especially on the task-switching task. Analyses found that only the Spanish-English bilinguals exhibited a smaller non-linguistic task-switching switch cost than the monolinguals, and not the Mandarin-English bilinguals. Moreover, Spanish-English bilinguals exhibited smaller switch costs in the non-linguistic task as compared to the Mandarin-English bilinguals. Indeed, it appears that there exists an explicit connection between a participant's history with code-switching and performance on the non-linguistic task-switching and language-switching tasks used in this study.

Yim and Bialystok (2012) examined the relationship between code-switching and cognitive functioning by administering an online measure of code-switching in order to calculate a code-switching score with which to correlate task- and language-switching performance. Cantonese-English bilinguals participated in the experiment. Like in Prior and Gollan (2011), participants completed a battery of cognitive and linguistic measures, which included task- and language-switching tasks. Analyses found that participants who engaged in more frequent code-switching (as measured by the code-switching score) were less affected by a change in instruction in the language-switching task than participants who less frequently code-switched, as evidenced by a reduced switching cost in this task. However, all bilinguals experienced a switch cost in the non-linguistic task. These results differ from those reported by Prior and Gollan (2011) and suggest that a one-to-one relationship between linguistic and non-linguistic switching does not exist.

Weissberger et al. (2012) examined whether the bilingual advantage extends across the lifespan. In particular, researchers compared young and aging bilinguals' performance on language-switching and task-switching tasks. If bilinguals recruit the same cognitive mechanisms across domains, then researchers expected to observe the same pattern of age-related decline in the two tasks. However, if bilinguals recruit different cognitive domains depending on domain, then researchers expected for performance on the two tasks to vary. Bilinguals experienced age-related switching costs in both tasks, but the effects were more prominent in the non-linguistic task.

The results from the above studies demonstrate that to date the findings are not conclusive. Some studies report findings that support the hypothesis that there is a shared mechanism recruited for successful codeswitching and task switching performance because the bilinguals who reported to frequently codeswitch outperformed monolinguals on the task switching task, whereas bilinguals who do not codeswitch performed no better than monolinguals (Prior & MacWhinney, 2010; Prior & Gollan, 2011; note that monolinguals cannot be tested on the language switching task, so no comparison could be made between performance on the language switching and the task switching tasks). Other findings suggest there exists a dissociation between the mechanisms recruited for each of the tasks because extensive experience with codeswitching did not relate to task switching success (Yim & Bialystok, 2012; Weissberger et al., 2012).

The main goal of the present study was to test the cognitive mechanisms of cognitive control in bilinguals and monolinguals in linguistic and non-linguistic contexts. In order to achieve this goal, three tasks were administered: an English lexical decision task and a generalized lexical decision task (both linguistic context), and a cued color-shape task (non-linguistic context). English-Spanish bilinguals, Spanish-English bilinguals and English monolinguals participated in the study. The English-Spanish bilinguals and English monolinguals completed the lexical decision tasks in their first language, English (Experiment 1). The Spanish-English bilinguals completed the lexical decision tasks in their second language, Spanish (Experiment 2). Currently, De Groot et al. (2000) and the present study are the only studies to examine homograph processing in the first and second language. De Groot et al. (2000) reported a homograph inhibition effect in both languages using behavioral methodologies. Finally, all three groups of participants completed the cued color-shape task.

Given that bilinguals have a unique experience with cognitive control as a result of managing the pervasive parallel activation of their two languages, the present study investigated whether bilinguals and monolinguals recruit the same cognitive mechanisms in linguistic and non-linguistic contexts. In the English lexical decision task, Spanish-English bilingual speakers should be sensitive to the interlingual homographs. They should respond to homographs more slowly than non-homograph controls as a result of response-based conflict. Meanwhile, English-Spanish bilinguals should respond to homographs as quickly as non-homograph controls. Monolingual speakers should show no differences in response latencies to interlingual homographs as compared controls. Native speakers of English (English-Spanish bilinguals and English monolinguals) should be slower to respond to intralingual homographs than to their non-homograph controls as a result of within-language competition at the semantic level. If experience managing cross-linguistic conflict enhances cognitive control, then English-Spanish bilinguals should demonstrate reduced interference. If Spanish-English bilinguals are highly proficient in English, they should show interference similar to the English-Spanish bilinguals.

In the generalized lexical decision task, bilingual speakers were expected to not show interlingual homograph inhibition. The two co-activated meanings of the homograph may compete early in the word recognition process, but because either meaning will lead to a correct response, this initial conflict should be resolved quickly, and long before a response is made. Assuming a horse race model, the first fully activated interpretation of a homograph would drive the homograph effect. By changing the task to a generalized lexical decision task, bilinguals should thus respond as soon as the stimulus is recognized as a word from either language. As a result, bilinguals should process homographs as quickly as, or perhaps faster than, non-homograph controls. Bilingual speakers were again expected to show the intralingual interference in the generalized lexical decision task. There were no predictions for monolinguals' possible homograph effects, because monolinguals did not perform this task.

Bilingual and monolingual speakers were expected to show switch costs in the non-linguistic task. That is, speakers should respond more slowly and less accurately when they have to switch response parameters from one trial to the next, relative to non-switch (consistent rule) trials. However, if linguistic conflict was resolved using the same cognitive mechanisms as in non-linguistic conflict, and if bilinguals' practice with language conflict and resolution extends to enhanced domain general cognitive control processes, then bilinguals were expected to be more successful at resolving conflict in the cued color-shape task. The magnitude of the switch effect, based on accuracy rates and processing times, should be smaller for bilingual speakers as compared to monolingual speakers.

Chapter 3

Experiment 1: Interlingual and Intralingual Homographs Presented in the First Language

Participants

Thirty-six English-Spanish bilingual and thirty-six English monolingual speakers were recruited from the student population at Pennsylvania State University. English-Spanish bilinguals were native English speaking late learners of Spanish. Specifically, they were enrolled in 400-level Spanish courses or in a graduate program offered by the Department of Spanish, Italian, and Portuguese. All participants reported being English dominant, see Tables 3-1 and 3-2.

Table **3-1**: Self-reported language ratings for English-Spanish bilinguals.

Language ratings (out of 10)	**L1 – English**	**L2 – Spanish**
Reading	9.8	7.5
Writing	9.7	7.4
Speaking	9.7	6.8
Comprehending	9.8	7.6
Average	**9.8**	**7.3**

Table **3-2**: Self-reported language ratings for English monolinguals.

Language ratings (out of 10)	L1 – English	L2 - Varied
Reading	9.7	2.5
Writing	9.5	2.1
Speaking	9.7	2.5
Comprehending	9.7	3.0
Average	**9.6**	**2.5**

Bilingual speakers' dominance was confirmed by comparing self-reports of language proficiency in English and Spanish from the language history questionnaire (on all four measures self-rated proficiency in English was higher than in Spanish, all p's $< .001$) and performance on the Boston naming task (performance in L1 ($M=82.7$, $SD=11.2$) was significantly better than in L2 ($M=26.9$, $SD=17.3$; $t(42)= 15.719$, $p<.001$). Bilingual speakers' average score for the DELE exam was 49.2 ($SD=12.1$) out of 100. English monolingual speakers had not received foreign language instruction past the introductory collegiate level and had not studied abroad in a foreign language-speaking country. English-Spanish bilinguals were slightly older ($M = 22.3$, $SD =2.4$) than the monolinguals ($M = 19.0$, $SD = 1.3$; $t(42)= 5.258$, $p<.001$). This fact is unsurprising given that the English-Spanish bilinguals were recruited from upper-level undergraduate courses and Spanish graduate programs, whereas the English monolinguals were recruited using the Penn State subject pool, which draws from introductory level psychology courses.

Eight English-Spanish bilingual speakers were excluded from analyses because of technical errors and six bilingual speakers were excluded from analyses because their accuracy on the non-linguistic conflict cued color-shape task was below chance (50%). Five English monolingual speakers were excluded from analyses because of technical errors and three monolingual speakers were excluded from analyses because their accuracy on the non-linguistic conflict cued color-shape task was below chance (50%). The remaining twenty-eight English monolingual speakers were matched individually to the twenty-two English-Spanish bilingual speakers on their English Boston Naming accuracy, which resulted in excluding an additional six English monolingual speakers. Twenty-two English-Spanish bilingual and twenty-two monolingual speakers were included the final data set.

Materials

Linguistic and non-linguistic conflict tasks

English lexical decision task

The English lexical decision task is an extension of the lexical decision tasks used in Van Heuven et al. (2008). Stimuli include interlingual homographs and controls. Interlingual homographs are words that share orthography but differ semantically and phonologically across languages (e.g., pan meaning 'bread' in Spanish). The set of interlingual homographs and controls consists of 36 English-Spanish interlingual homographs, 36 matched English controls, 144 English pseudowords (e.g., distription, shringe) and 72 filler language-specific (non-homograph, non-cognate) English words. Homographs are matched on an individual basis to their non-homograph control words. The CELEX database was used to match homographs and non-homograph control words on frequency and number of phonemes and the English Lexicon Project was used to match the number of orthographic neighbors (see Table 3-3).

Table **3-3**: Lexical properties of the interlingual and intralingual homographs.

Word type	Length	Frequency	Number of phonemes	Number of orthographic neighbors
Interlingual homograph	5.44	1.11	4.51	5.69
Interlingual non-homograph matched control	5.47	1.09	4.54	5.17
Intralingual homograph	5.74	1.11	4.25	4.75
Intralingual non-homograph matched control	5.28	.97	4.36	5.92

In order to study linguistic conflict in monolinguals and to examine whether the same cognitive mechanisms used in bilinguals are used in monolinguals, the stimuli also include a set of intralingual homographs and controls. Intralingual homographs are words that share orthography but have more than one meaning in one language (e.g., chest meaning a storage container and a body part in English). Specifically, these stimuli examine whether the same cognitive mechanisms used in bilinguals to solve within-language conflict are used in monolinguals, as well as to test whether bilinguals resolve across- and within-language conflict using the same cognitive mechanisms.

Like the interlingual homographs and their matched controls, the set of intralingual homographs and controls consists of 36 English intralingual homographs, 36 matched English control words, 144 pseudowords and 72 filler language-specific (non-homograph, non-cognate) English words. Intralingual homographs and their non-homograph control words were matched to each other using the methods to match the interlingual homographs and their non-homograph control words. Interlingual and intralingual homographs were also matched to each other on word length and frequency.

Generalized lexical decision task

The generalized lexical decision task is an extension of the lexical decision tasks used in the previously discussed fMRI study by Van Heuven et al. (2008). The stimuli in this task consist of 576 letter strings and are identical to those tested in the English lexical decision task.

Cued color-shape task

The non-linguistic test is an extension of the cued color-shape task switching paradigm employed in the study by Garbin et al. (2010). The task includes four stimuli and two instructional cues. The four stimuli are a red circle, red square, blue circle, and blue square. The two instructional cues are a band of black shapes and a band of colors.

Procedure

Participants were tested in two different sessions spaced 5-10 days apart. On the first day of testing, participants completed a language history questionnaire and individual differences measures (described in more detail below). Monolinguals completed the O-Span Task, Boston Naming Task in English, and Flanker Task. Bilinguals completed the O-Span Task, DELE, Boston Naming Task in their weaker language, Flanker Task, and then Boston Naming Task in their dominant language.

Language proficiency measures

Two measures of language proficiency were administered to both bilingual and monolingual participants: a language history questionnaire and the Boston naming task (Kaplan, Goodglass, & Weintraub, 2001). For the bilingual participants, a third task was administered: a modified version of a standardized exam typically administered by the Diplomas of Spanish as a Foreign Language (DELE; Ministry of Education, Culture, and Sport of Spain, 2006).

Language history questionnaire

The language history questionnaire collected self-ratings of proficiency in reading, writing, speaking, and comprehension, as well as a detailed history of the participants' language exposure, use, and learning history. For the bilinguals, there were also several questions from the Bilingual Switching Questionnaire (Rodriguez-Fornells et al. 2012), assessing an individual's codeswitching tendencies. The questionnaire was administered using Google Docs.

Boston naming task

The Boston Naming Task is a standardized vocabulary test that consists of sixty images, all black-and-white line drawings (Goodglass, Kaplan, & Weintraub, 2001). The images were presented on a computer screen on a white background, and participants were instructed to name these images out loud as quickly and accurately as possible. Bilinguals first completed the task in their weaker language and then later, in the same testing session, they completed the task in their dominant language, as determined by their self-ratings in the language history questionnaire.

Monolinguals completed this task in their only language (English). This task was programmed in e-Prime.

Trials began with a fixation cross presented for 750 ms, followed by a 1500 ms blank screen. The image was presented on the screen until the participant responded, or for a maximum of 5000 ms. There was then a 600 ms blank inter-stimulus interval. The experiment began with a practice session consisting of 8 novel items. These items were presented in an identical fashion to the experimental trials and randomly ordered for each participant. Experimental items were always presented in the same order, increasing in difficulty.

Oral responses were registered by a voice-key function of the e-Prime response box. Because the voice key could be triggered by an extraneous noise (e.g., a cough or “um”) and sometimes did not trigger at the beginning of the response, the experimenter remained in the testing chamber throughout this task and recorded whether or not participant’s responses were accurately registered by the voice-key function. Reaction times (RTs) for trials with inaccurate triggers were removed from analyses. The entire task was audio recorded for later transcription and accuracy analyses. RTs for incorrect responses were also removed from analyses.

DELE task

The DELE is a standardized written test of Spanish knowledge. The test consisted of a comprehension section, in which bilingual participants selected the best option with which to fill the blank within the context of paragraphs and sentences. There were also sections testing the participants’ knowledge of grammar and vocabulary. The test was administered using an enabled Word document.

Cognitive measures

Two measures were used to examine individual differences in cognitive functioning: the Flanker task (adapted from Emmorey, Luk, Pyers, & Bialystok, 2008) and the Operation Span ("O-Span"; Turner & Engle, 1989).

Flanker task

The Flanker task is a measure of cognitive control. In the task, a red arrow was presented on the computer screen. Participants were asked to indicate by button press which direction the red arrow was pointing toward. Depending on the block, the red arrow could be flanked by an object. The surrounding objects included black arrows, black diamonds, and black X's. The arrows either faced the same direction as the red arrow, providing congruent information, or the opposite direction, providing incongruent information. On the other hand, the diamonds functioned as irrelevant visual information and had no impact on how the participant should respond, whereas the X's indicated that the participant should withhold their response.

Practice trials preceded each block of experimental trials. An equal number of each trial type was presented in each block. In the first block, the red arrow was presented alone and faced either toward the left or the right. In the second block, diamonds and X's surrounded the red arrow. The diamonds represented "go" trials and the X's "no-go" trials. In the third block, black arrows surrounded the red arrow. The black arrows either altogether faced toward the left or the right. In the fourth block, the instructions were mixed such that all of the trial types were tested. After the mixed block, the level of difficulty decreased. First, there was another congruent/incongruent block with black arrows. Then, there was a go/no-go block with the diamonds and X's. Last, there was a block with only the red arrow. This combination of blocks allowed for response inhibition and interference suppression to be measured. Response inhibition was measured by comparing responses when X's surround the red arrow as compared to when the arrow was presented alone. Interference suppression was measured by comparing responses to the red arrow surrounded by incongruent black arrows to responses to the red arrow surrounded by congruous black arrows.

Trials began with a fixation cross presented for 250 ms and then the image, which remained on the screen until the participant responded or 2000 ms had elapsed. Within blocks, items were randomly presented. The Flanker task was programmed in e-Prime.

Operation-Span task

The O-Span task is a measure of working memory (Turner & Engle, 1989). Participants were asked to judge whether a simple arithmetic problem is correct or not by button press, as quickly and accurately as possible. At the same time, they were asked to remember 2-6 words from their dominant language, which had been interleaved between the math problems. At the end of each block, the word 'RECALL' appeared in the center of the screen. Participants were instructed to type as many words as they could recall from the set as possible at this time. They were not asked to recall the words in the order in which they were presented, but they were instructed to not type the last word they saw as the first word in their recall list.

The O-Span task was divided into 5 sections, increasing in complexity. In each section, there were three sets of trials. The task began with a set size (equation and word) of two and increased in linear order to a set size of six. For example, in the first block, participants decided whether two equations had been solved correctly while memorizing the two words that were presented between the equations. Larger amounts of words correctly recalled and better judgment of math problems are considered to reflect better working memory.

Trials began with a fixation cross presented for 1000 ms, followed by a math problem that remains on the screen until the participant responded or 3750 ms had elapsed. Afterward, a word was presented in the center of the screen for 1250 ms. Problems and words continued to alternate until the end of the block at which point the participants recalled the words from the set. There was no time limit on how long the participants had to type in the words they recall. Items were always randomly presented within a set. The task was always run in what the participant reported as their dominant language, with the Spanish version of the task using Spanish translations of the English stimuli. The O-Span task was programmed in e-Prime.

On the second day of testing, the participants completed the linguistic and non-linguistic conflict tasks. Monolinguals were administered the English lexical decision task and the cued color-shape task. The order of these tests was counterbalanced between participants. Bilinguals were administered the English lexical decision task, cued color-shape task, and generalized lexical decision task.

Linguistic and non-linguistic conflict tasks

English lexical decision task

Bilingual and monolingual participants were asked to respond by button press indicating whether or not each letter string formed a word in English. In the first half of the task, bilinguals' and monolinguals' sensitivity to interlingual homographs was tested (no homograph effect was expected for the monolinguals). In the second half of the task, bilinguals' and monolinguals' sensitivity to intralingual homographs was tested.

Trials began with the presentation of the fixation cross for 500 ms, followed by the letter string for 500 ms. Reaction time and accuracy on decision-making were recorded. Button press triggered the presentation of the next stimulus. The task itself was comprised of 4 blocks. The first two blocks contained the interlingual homographs and the matched controls, and the second two blocks contained the intralingual homographs and the matched controls. Each block contained 18 homographs, 18 matched controls, 72 pseudowords, and 36 filler words. The order of stimuli presentation for each participant was pseudo-randomized within each block.

Generalized lexical decision task

Bilingual participants were instructed to indicate by button press whether each letter string formed an acceptable word across their two languages (English or Spanish). In the first half of the task, bilinguals' sensitivity to interlingual homographs was tested (no homograph effect was expected for the monolinguals). In the second half of the task, bilinguals' sensitivity to intralingual homographs was tested. Monolinguals did not perform this task.

The design of the generalized lexical decision task was identical to that of the English lexical decision task. However, the stimulus set was divided into four different blocks than the blocks used in the English task. The order of stimuli presentation for each participant was then pseudo-randomized within each block.

Cued color-shape task

Bilingual and monolingual participants were asked to identify by button press each stimulus's color or shape. The stimulus was either a circle or a square. Each object was either red or blue. At the same time as stimulus presentation, an instructional cue appeared below the stimulus. A band of black shapes indicated that the participant should respond according to the shape of the object; a spectrum of colors indicated that the participant should respond according to the color of the object. Specifically, participants were instructed to identify the correct feature by pushing one of two buttons: the right-most button if the figure was a circle or red (depending on the cue), and the left-most button if the figure was a square or blue (again depending on the cue). In this non-linguistic test, bilingual and monolingual participants needed to resolve both stimulus- and response-based conflict, because task instructions forced participants to inhibit their desire to respond according to the previous trial's instruction.

Trials began with presentation of a fixation cross for 500 ms. Afterward, the stimulus (circle or square) and instructional cue was presented on the screen for 1000 ms. Reaction time and accuracy on decision-making were recorded. Button press did not trigger the presentation of the next stimulus. The cued color-shape task was comprised of two blocks, with the order of blocks counterbalanced across participants. Each block contained 64 stimulus events (16 switch and 16 non-switch events), which was formed by pairing together two consecutive stimulus presentations. For example, if the cue differed for the pair of stimulus, then a switch event was formed in which the participant needed to respond according to both color and shape, and thus the participant needed to mentally switch which instructional cue they were referring to when responding.

Results

Before statistical data analysis, all data were cleaned for outliers. Absolute outliers were defined as response latencies below 300 ms and above 3000 ms. Response latencies that were outside these boundaries were excluded from analysis. For each condition of each task, relative outliers were calculated based on the mean response latency for each participant's performance on correct trials. Relative outliers were response latencies that fell above or below 2.5 standard deviations from this mean. Relative outliers were excluded from further analysis. The linguistic and non-linguistic conflict tasks were analyzed running a series of ANOVAs with subjects (F1) and items (F2) as random factors was conducted. In the by-subject analysis, the factor speaker (English-Spanish bilingual, monolingual, or Spanish-English bilingual) is treated as a between-subject variable and the factor stimuli (interlingual homograph, intralingual homograph, or control word) is treated as a within-subject variable. In the by-item analysis, speaker is treated as a within-subject variable and stimuli as a between-subject variable.

English lexical decision task

To examine cross- and within-language conflict in a language-specific context, response latency data from the English lexical decision task were analyzed by conducting two ANOVAs. A 2 speaker (bilingual vs. monolingual) x 2 cross-language stimuli (interlingual homograph vs. control) ANOVA with subjects (F1) and items (F2) as random factors was conducted. A 2 speaker (bilingual vs. monolingual) x 2 within-language stimuli (intralingual homograph vs. control) ANOVA with subjects (F1) and items (F2) as random factors was also conducted.

In the English lexical decision task, the main effect of cross-language stimuli was significant in the by-subject analysis, but not the by-item analysis ($F1(1,42) = 5.253$, $p<.027$, $F2(1,70) = .079$, $p=.674$); interlingual homographs ($M=613$ ms; $SD= 127$) were recognized 16 ms faster than non-homograph controls ($M=629$ ms; $SD=130$). The main effect of speaker was significant in the by-item analysis, but not the by-subject analysis ($F1(1,42) = .338$, $p<.564$, $F2(1,70) = 4.011$, $p=.049$). The interaction between speaker and cross-language stimuli was not significant ($F1(1,42) = .212$, $p=.648$, $F2(1,70) = .639$, $p=.427$). Mean response latencies are shown in Figure 3-1.

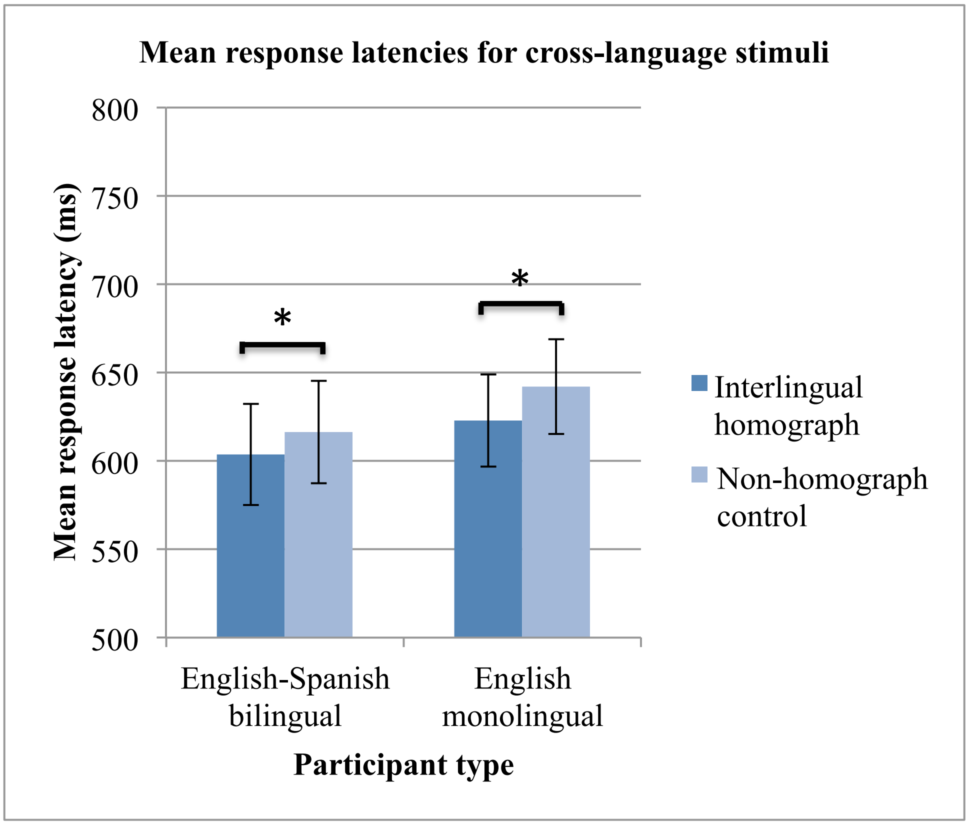

Figure **3-1**: Mean response latencies for the cross-language stimuli in the English lexical decision task in Experiment 1.

In the English lexical decision task, the main effect of within-language stimuli was significant (F1(1,42) = 49.398, p<.001, F2(1,70) = 4.460, p=.038); intralingual homographs (M=601 ms; SD= 101) were recognized 41 ms faster than non-homograph controls (M=642 ms; SD=104). The main effect of speaker was not significant in the by-subject analysis (F1(1,42) = .472, p=.496) but it was significant on the by-item analysis (F2(1,70) = 9.351, p=.003). The interaction between speaker and within-language stimuli was not significant (F1(1,42) = .014, p=.907, F2(1,70) = .186, p=.667). Mean response latencies are shown in Figure 3-2.

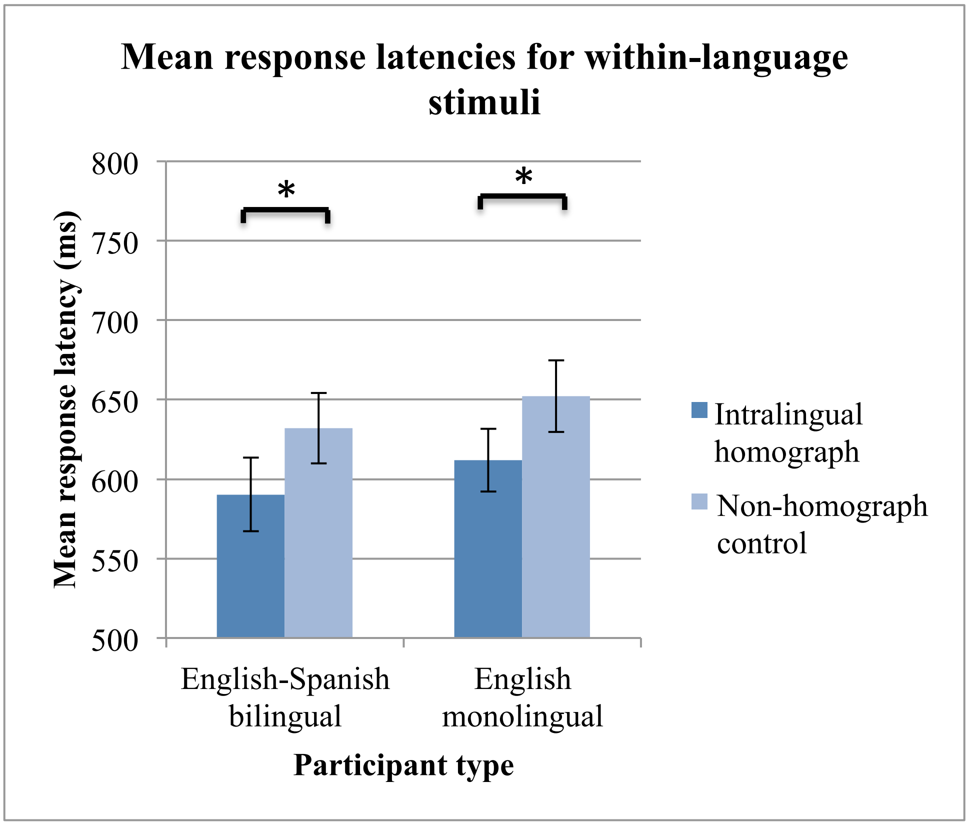

Figure **3-2**: Mean response latencies for the within-language stimuli in the English lexical decision task in Experiment 1.

Generalized lexical decision task

To examine cross- and within-language conflict in a language non-specific context, bilingual response latency data from the generalized lexical decision task were analyzed by conducting two one-factor repeated measures ANOVAs. A cross-language stimuli (interlingual homograph vs. control) ANOVA with subjects (F1) and items (F2) was conducted. A within-language stimuli (intralingual homograph vs. control) ANOVA with subjects (F1) and items (F2) was also conducted.

In the generalized lexical decision task, the main effect of cross-language stimuli from the bilingual response latency data task was not significant ($F1(1,21) = .237$, $p=.631$, $F2(1,70) =$

.001, p=.975). The main effect of within-language stimuli was significant (F1(1,21) = 13.603, p=.001, F2(1, 70) = 3.539, p=.064); intralingual homographs (M=561 ms; SD= 85) were recognized 34 ms faster than non-homograph controls M=595 ms (SD=105). Mean response latencies are shown in Figures 3-3 and 3-4.

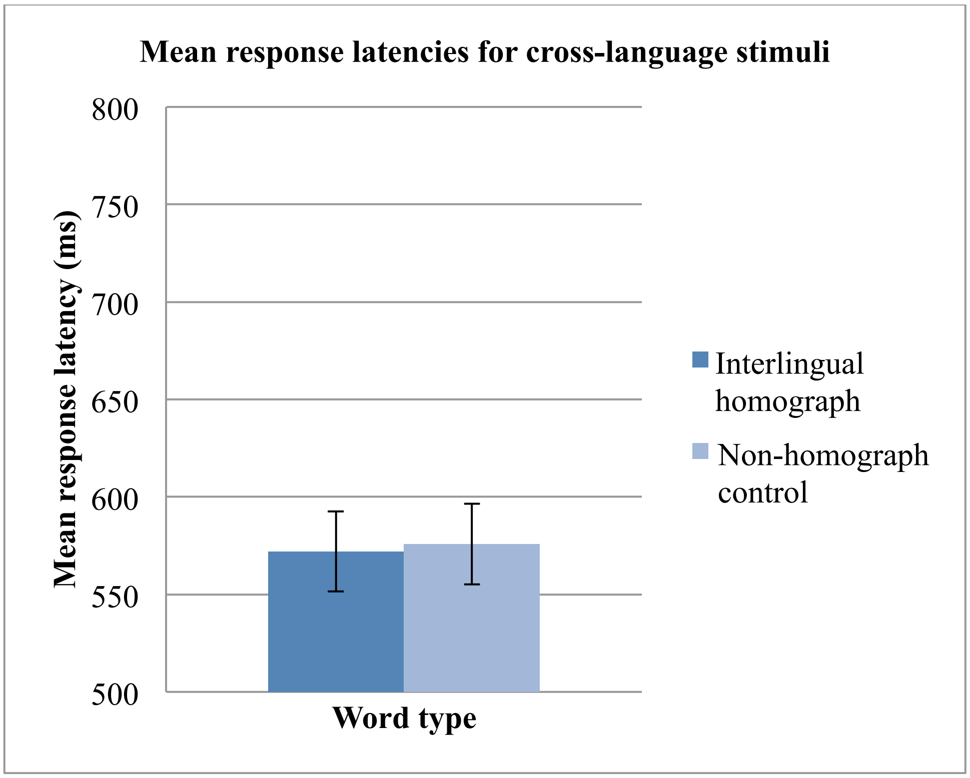

Figure **3-3**: Mean response latencies for the cross-language stimuli in the generalized lexical decision task in Experiment 1.

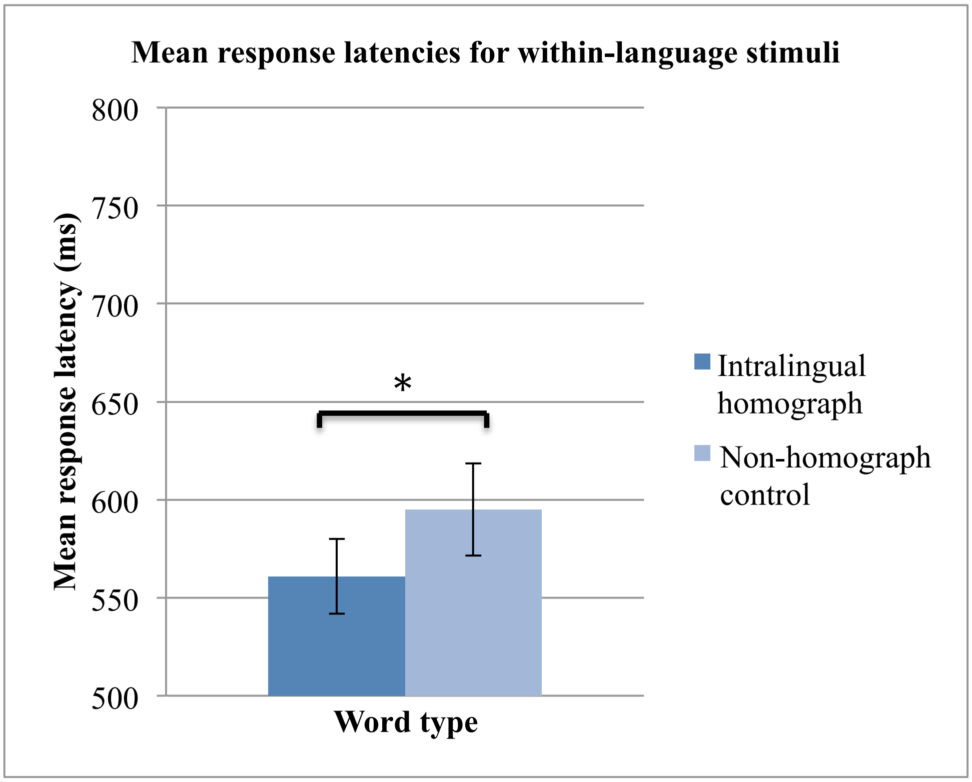

Figure **3-4**: Mean response latencies for the within-language stimuli in the generalized lexical decision task.

Bilingual performance on the English and generalized lexical decision tasks

To examine cross- and within-language conflict across language-specific and non-specific contexts, bilingual response latency data from across the English and generalized lexical decision tasks were analyzed by conducting two ANOVAS. A 2 task (English vs. generalized) x 2 cross-language stimuli (interlingual homograph vs. control) ANOVA with subjects (F1) and items (F2) as random factors was conducted. A 2 task (English vs. generalized) x 2 within-language stimuli (intralingual homograph vs. control) with subjects (F1) and items (F2) as random factors was also conducted.

The main effect of task for the bilingual response latency data from the English and generalized lexical decision tasks approached significance on the by-subject analysis (F1(1,21) = 3.690, p=.068) and was significant by-item (F2(1,70) = 24.010, p<.001); cross-language stimuli from the English lexical decision task (M=610 ms; SD= 134) were recognized 37 ms slower than stimuli from the generalized task M=573 ms (SD=91). The main effect of cross-language stimuli was not significant (F1(1,21) = 1.435, p=.244, F2(1,70) = .108, p=.743). The interaction between task and cross-language stimuli was not significant (F1(1,21) = .476, p=.498, F2(1,70) = .545, p=.463). Mean response latencies are shown in Figure 3-5.

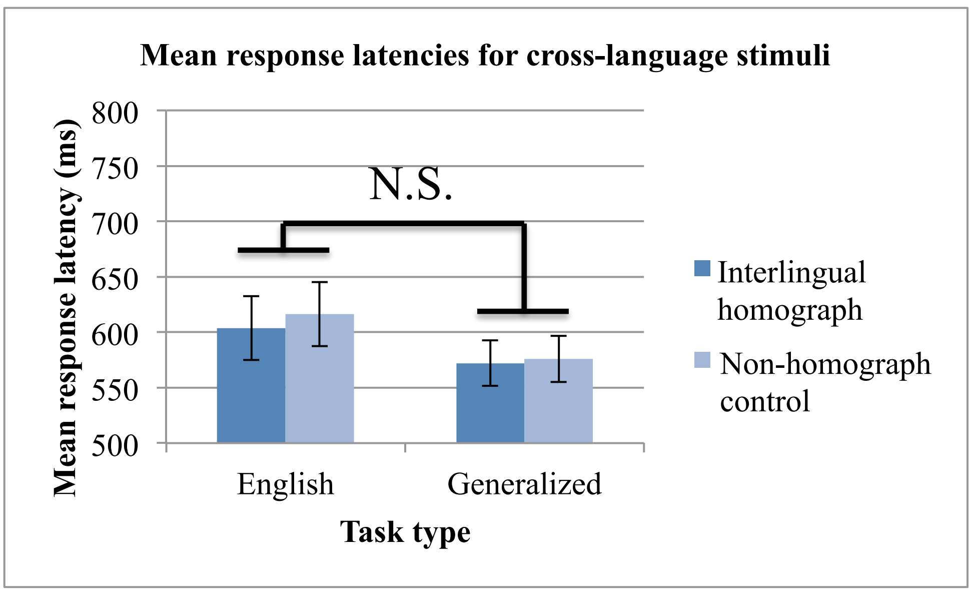

Figure **3-5**: Mean response latencies for the cross-language stimuli across the lexical decision tasks in Experiment 1.

The main effect of task for the bilingual response latency data from the English and generalized lexical decision tasks was significant (F1(1,21) = 4.470, p=.047, F2(1,70) = 18.082, p<.001); within-language stimuli from the English lexical decision task (M=611 ms; SD= 107) were recognized 33 ms slower than stimuli from the generalized task (M=578 ms; SD=96). The main effect of within-language stimuli was also significant (F1(1,21) = 37.780, p<.001, F2(1,70)

= 5.183, p=.026); intralingual homographs (M=575 ms; SD= 98) were recognized 38 ms faster than non-homograph controls (M=613 ms; SD=105). The interaction between task and within-language stimuli was not significant (F1(1,21) = .486, p=.493, F2(1,70) = .458, p=.501). Mean response latencies are shown in Figure 3-6.

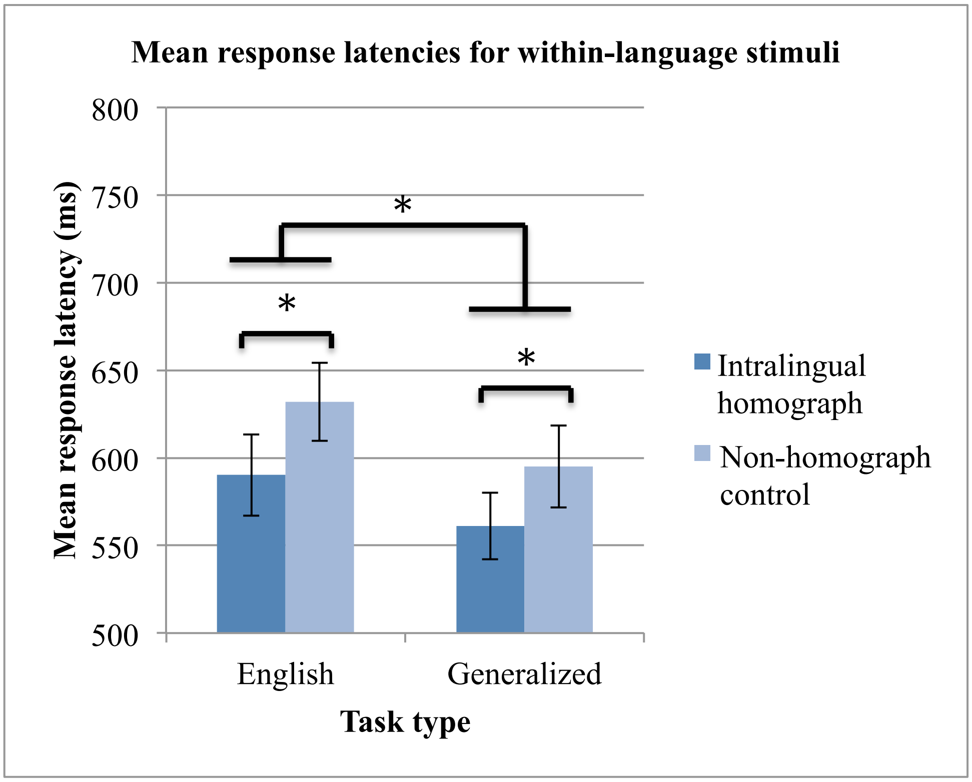

Figure **3-6**: Mean response latencies for the within-language stimuli across lexical decision tasks in Experiment 1.

Cued color-shape task

To examine non-linguistic conflict, data from the cued-color shape task were analyzed by conducting two ANOVAs. A 2 speaker (bilingual vs. monolingual) x 2 trial type (switch vs. non-switch) ANOVA on response latency with subjects (F1) as random factors was conducted. A 2 speaker (bilingual vs. monolingual) x 2 trial type (switch vs. non-switch) ANOVA on response accuracy with subjects (F1) as random factors was also conducted.

In the cued color-shape task, the main effect of trial type on response latency was significant (F1(1,42) = 36.461, p<.001); switch trials (M=758 ms; SD=49) were recognized 32 ms slower than non-switch trials (M=726 ms; SD=50). The main effect of speaker type was also significant (F1(1,42) = 4.241, p=.046); English-Spanish bilinguals (M=728 ms; SD=12) were 28 ms faster than English monolinguals (M=756 ms; SD=9). The interaction between speaker type (bilingual vs. monolingual) and trial type (switch vs. non-switch) was not significant (F1(1,42) = 1.259, p=.268). Mean latencies are shown in Figure 3-7.

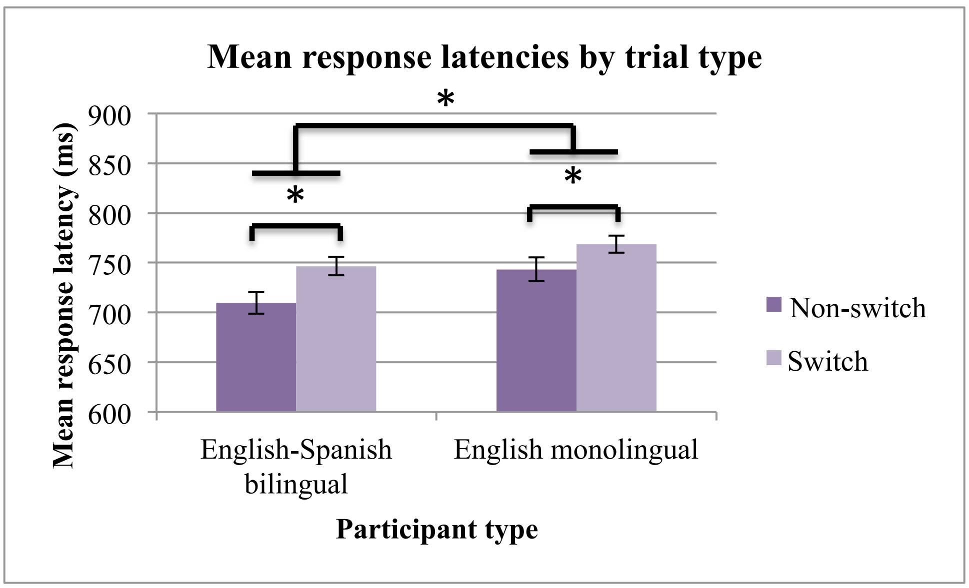

Figure **3-7**: Mean response latencies for the cued color-shape task in Experiment 1.

In the cued color-shape task, the main effect of trial type on accuracy was also significant (F1(1,42) = 62.237, p<.001); switch trials (M=65; SD=15) were recognized 10% less accurately than non-switch trials (M=75; SD=12). The main effect of speaker type was not significant (F1(1,42) = 1.569, p=.217). The interaction between speaker type (bilingual vs. monolingual) and trial type (switch vs. non-switch) was not significant (F1(1,42) = .515, p=.477). Mean accuracies are shown in Figure 3-8.

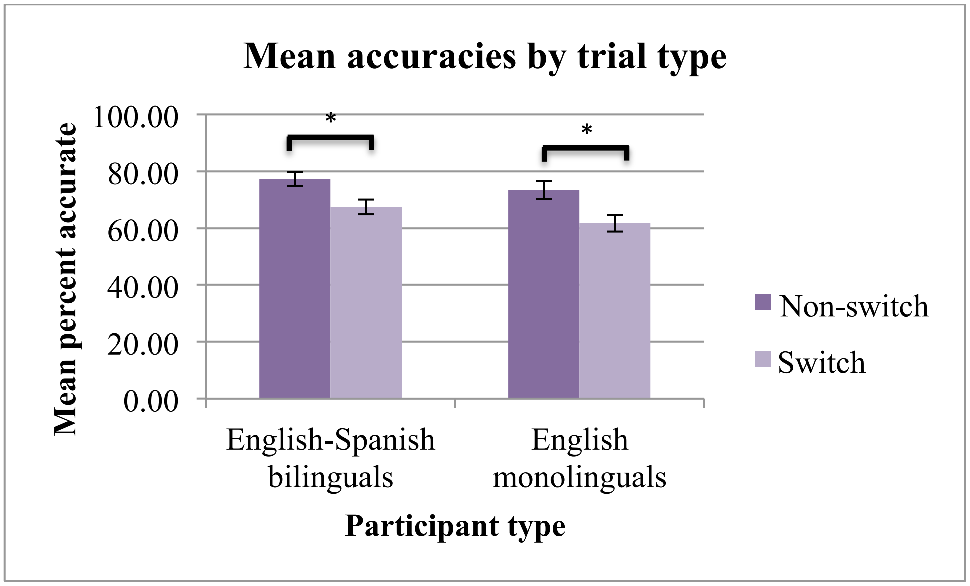

Figure **3-8**: Mean accuracies for the cued color-shape task in Experiment 1.

Correlational analyses

We performed a correlational analysis on the response latency data in order to combine performance on the linguistic and non-linguistic conflict tasks. The analysis included the following measures: the interlingual homograph effect in the English lexical decision task, the intralingual homograph effect in the English lexical decision task, the interlingual homograph effect in the generalized lexical decision task (for the English-Spanish bilinguals only), the intralingual homograph effect in the generalized lexical decision task (for the English-Spanish bilinguals), and the switch effect. The homograph effect was calculated as the mean response latency for the homograph minus the mean response latency for the matched non-homograph control. The switch effect was calculated as the mean response latency across conditions (color-shape and shape-color) minus the mean response latency across non-switch conditions (color-color and shape-shape). A correlational analysis was first conducted collapsed across all of the participants in Experiment 1. Afterward, two separate correlational analyses were conducted split by participant group (English-Spanish bilingual and English monolingual.) Specifically, we were interested in examining whether conflict resolution in the English lexical decision task correlated with conflict resolution in cued color-shape task across speakers, and in particular for speakers with the same native language, whether conflict resolution in the English lexical decision task correlated with conflict resolution in cued color-shape task for different speaker types (English-Spanish bilinguals, English monolinguals), and whether conflict resolution in the generalized lexical decision task correlated with conflict resolution in cued color-shape task only for English-Spanish bilinguals.

For the English lexical decision task, the overall correlations between the interlingual homograph effect and the switch effect ($r(44) = -.125$, $p = .418$) and the intralingual homograph effect and the switch effect ($r(44) = -.097$, $p = .530$) were not significant. The correlation between the interlingual homograph effect and the switch effect was not significant for the bilingual speakers ($r(22) = -.094$, $p =.677$) or the monolinguals ($r(22) = -.250$, $p = .263$). Likewise, the correlation between the intralingual homograph effect and the switch effect was not significant for the bilingual speakers ($r(22) = -.057$, $p = .801$) or the monolingual speakers ($r(22) = -.170$, $p = .448$).

For the generalized lexical decision task, the correlation between the interlingual homograph effect and the switch effect was not significant ($r(42) = -.002$, $p = .993$). However, the correlation between the intralingual homograph effect and the switch effect was significant ($r(42) = -.472$, $p = .027$).

Cognitive measures

The Operation Span score refers to the number of trials where the word was correctly recalled and the math equation was correctly solved, with the highest possible score being 60. Higher Operation Span scores are interpreted as indicating better working memory. The Flanker effect is calculated as the mean incongruent response latency minus the mean congruent response latency from the congruent/incongruent block. Smaller Flanker effects are interpreted as indicating better inhibitory control. The O-Span scores of the English-Spanish bilinguals were slightly better than those of the monolinguals ($t(42) = 1.989$, $p=.053$), with English-Spanish bilinguals ($M=50.3$, $SD=5.0$) scoring 2.8 higher than English monolinguals ($M=47.5$, $SD=4.3$). The Flanker effect of the English-Spanish bilinguals was no different than that of the English monolinguals ($t(42) = 1.592$, $p=.119$). These data support an increasing number of studies finding no consistent bilingual advantage in executive functioning (e.g., Hernández, Costa-Faidella, & Sebastián-Gallés, 2009; Hernández, Martin, Barcélo, & Costa, 2013; Morton & Harper, 2007; Paap & Greenberg, 2013).

Discussion

In Experiment 1, English-Spanish bilinguals experienced significant interlingual and intralingual facilitation in the English lexical decision task. Similarly, English monolinguals also experienced significant interlingual and intralingual facilitation in the English lexical decision task. In the generalized lexical decision task, which only the bilinguals completed, English-Spanish bilinguals experienced significant intralingual facilitation, but no interlingual homograph effect. Moreover, response latencies were generally slower for the English task than the generalized task, indicating that task instruction affects processing time. The interlingual facilitation is surprising given that the majority of previous studies examining interlingual homograph processing have reported interference. However, most studies that have found this effect have tested bilinguals in their second language, where co-activation of the dominant language leads to competition at the semantic level between the two activated languages and slows down responses. Our study tested bilinguals in their first language, where activation of the dominant language reaches threshold before co-activation of the weaker language can lead to competition at the semantic level.

The cued color-shape task yielded a significant switch cost for response latency and accuracy. There was also a significant effect of speaker type on response latency such that bilinguals required less time overall to process each trial, which suggests that bilinguals do not need the same amount of time as monolinguals to process non-linguistic information. However, relationships between the different homograph effects and the switch effect did not consistently correlate with each other, which suggests that there is not a direct relationship between the cognitive mechanisms used to resolve the linguistic and non-linguistic conflict examined in this experiment.

In Experiment 2, we recruited a group of bilinguals with Spanish as their native language. We examined whether Spanish-English bilinguals completing the language-specific lexical decision task in their L2 English would experience interference. In particular, we hypothesized that the interlingual facilitation should disappear and be replaced by interference, because participants will experience semantic competition from their co-activated L1 Spanish.

Chapter 4

Experiment 2: Interlingual and intralingual homographs presented in the second language

Participants

Twenty-nine Spanish-English bilingual speakers were recruited from the student population at Pennsylvania State University. These participants were native Spanish speaking late learners of English. All of participants reported being Spanish dominant, see Table 4-1.

Table **4-1**: Self-reported language ratings for Spanish-English bilinguals.

Language ratings (out of 10)	**L1 - Spanish**	**L2 - English**
Reading	9.9	9.1
Writing	9.8	7.7
Speaking	9.8	7.9
Comprehension	9.9	9.1
Average	**9.8**	**8.4**

Bilingual speakers' dominance was confirmed by comparing self-reports of language proficiency in English and Spanish from the language history questionnaire (on all four measures self-rated proficiency in Spanish was higher than in English, all p's $< .001$) and performance on the Boston naming task (performance in L1 ($M=76.00$, $SD=13.7$) was significantly better than in

L2 (M=52.7, SD=17.0); t(19)= 7.070, p<.001). Bilingual speakers' average score for the DELE exam was 87.10 (SD=5.6) out of 100. The mean age of the bilinguals was 30.50 years (SD=9.0).

Four Spanish-English bilingual were excluded from analyses because of not fulfilling the study's requirements (participants were dominant in English) and five bilingual speakers were excluded from analyses because their accuracy on the non-linguistic conflict cued color-shape task was below chance (50%). As a result, twenty Spanish-English bilingual speakers were included in the final data set.

Materials

Linguistic and non-linguistic conflict tasks

English lexical decision task

Stimuli were identical to the homographs and controls tested in the English lexical decision task from Experiment 1.

Generalized lexical decision task

Stimuli were identical to the homographs and controls tested in the English lexical decision task from Experiment 1.

Cued color-shape task

Stimuli were identical to those used in the cued color shape test from Experiment 1.

Procedure

As in Experiment 1, participants were tested in two different sessions spaced 5-10 days apart. On the first day of testing, participants completed a language history questionnaire and individual differences measures. Participants completed the O-Span Task, DELE, Boston Naming Task in their weaker language, Flanker Task, and then Boston Naming Task in their dominant language.

Language proficiency measures

The same language measures described in Experiment 1 (language history questionnaire, Boston naming task, and a modified version of the DELE exam) were administered. For a complete description of each measure, please refer to the Procedure section of Experiment 1.

Cognitive measures

The same cognitive measures described in Experiment 1 (Flanker task and O-Span task) were administered. See the Procedure section of Experiment 1 for a complete description of each measure.

As in Experiment 1, participants completed the linguistic and non-linguistic conflict tasks (i.e., English lexical decision task, cued color-shape task, and generalized lexical decision task) on the second day of testing.

Linguistic and non-linguistic conflict tasks

English lexical decision task

Task instructions for the English lexical decision task were identical to those of Experiment 1. For a complete description of the instructions, see the Procedure section of Experiment 1.

Generalized lexical decision task

Task instructions for the generalized lexical decision task were identical to those of Experiment 1. For a complete description of the instructions, see the Procedure section of Experiment 1.

Cued color-shape task

Task instructions for the cued color-shape task were identical to those of Experiment 1. For a complete description of the instructions, see the Procedure section of Experiment 1.

Results

Behavioral data from the linguistic and non-linguistic conflict tasks were cleaned for outliers in the same manner as in Experiment 1.

English lexical decision task

To examine cross- and within-language conflict in a language-specific context, response latency data from the English lexical decision task were analyzed by conducting two one-factor repeated measures ANOVAs. A cross-language stimuli (interlingual homograph vs. control) ANOVA with subjects (F1) and items (F2) as random factors was conducted. A within-language stimuli (intralingual homograph vs. control) ANOVA with subjects (F1) and items (F2) as random factors was also conducted.

In the English lexical decision task, the main effect of cross-language stimuli was not significant ($F1(1,19) = .021$, $p=.887$, $F2(1,70) = .006$, $p=.941$). The main effect of within-language stimuli was significant in the by-subject analysis, but not the by-item analysis ($F1(1,19) = 7.241$, $p=.014$, $F2(1,70) = 1.278$, $p=.262$); intralingual homographs ($M=747$ ms; $SD=145$) were recognized 27 ms faster than non-homograph controls ($M=774$ ms; $SD=136$). Mean response latencies are shown in Figures 4-1 & 4-2.

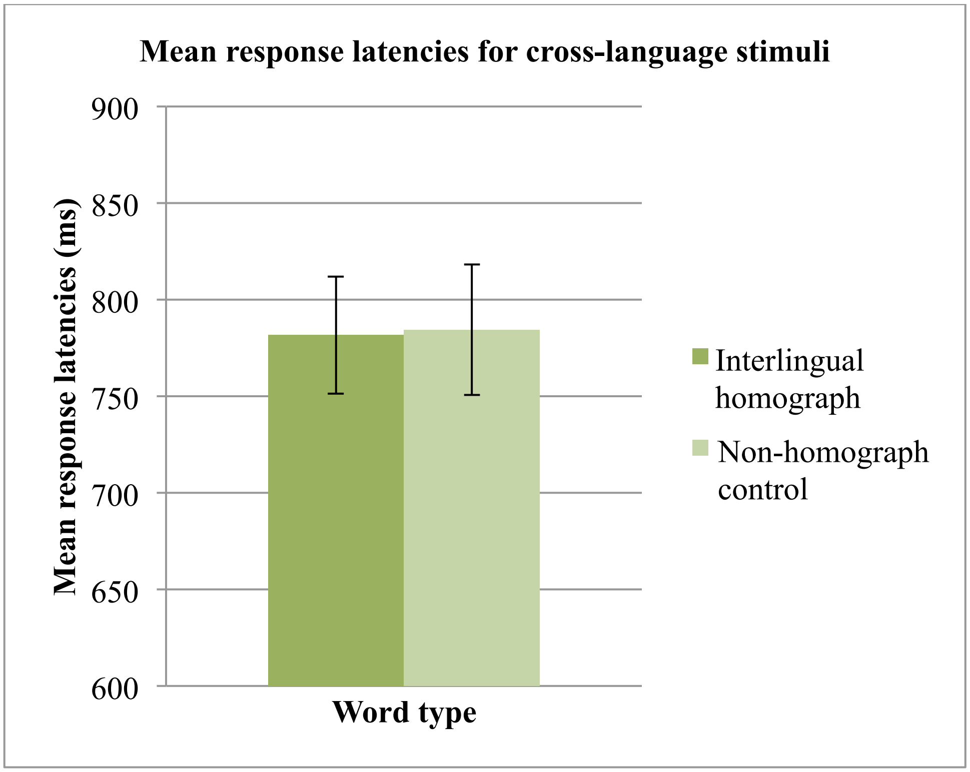

Figure **4-1**: Mean response latencies for the cross-language stimuli in the English lexical decision task in Experiment 2.

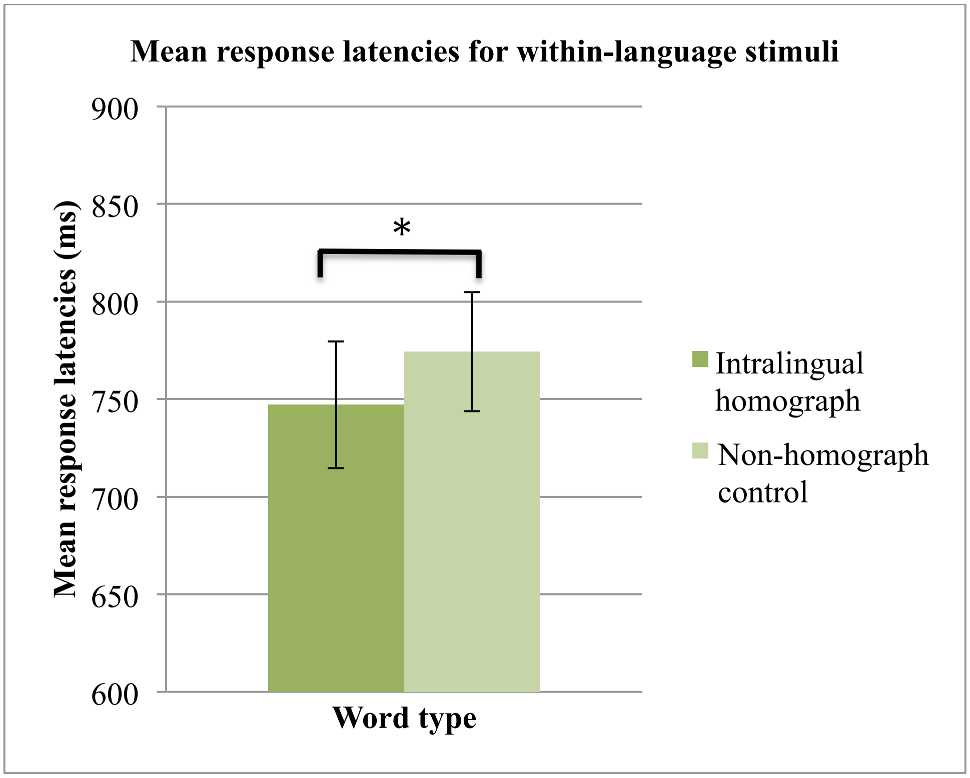

Figure **4-2**: Mean response latencies for the within-language stimuli in the English lexical decision task in Experiment 2.

Generalized lexical decision task

To examine cross- and within-language conflict in a language non-specific context, bilingual response latency data from the generalized lexical decision task were also analyzed by conducting two one-factor repeated measures ANOVAs. A cross-language stimuli (interlingual homograph vs. control) ANOVA with subjects (F1) and items (F2) as random factors was conducted. A within-language stimuli (intralingual homograph vs. control) ANOVA with subjects (F1) and items (F2) as random factors was also conducted.

In the generalized lexical decision task, the main effect of cross-language stimuli t-test was significant in the by-subject analysis, but only trended toward significance in the by-item analysis (F1(1,19) = 9.836, p=.005, F2(1,70) = 2.220, p=.141); interlingual homographs (M=672 ms; SD=106) were recognized 40 ms faster than non-homograph controls (M=712 ms; SD=147). The main effect of within-language stimuli was also significant in the by-subject analysis and trending toward significance in the by-item analysis (F1(1,19) = 7.982, p=.011, F2(1,70) = 2.470, p=.121); intralingual homographs (M=668 ms; SD=108) were recognized 27 ms faster than non-homograph controls (M=695 ms; SD=108). Mean response latencies are shown in Figures 4-3 & 4-4.

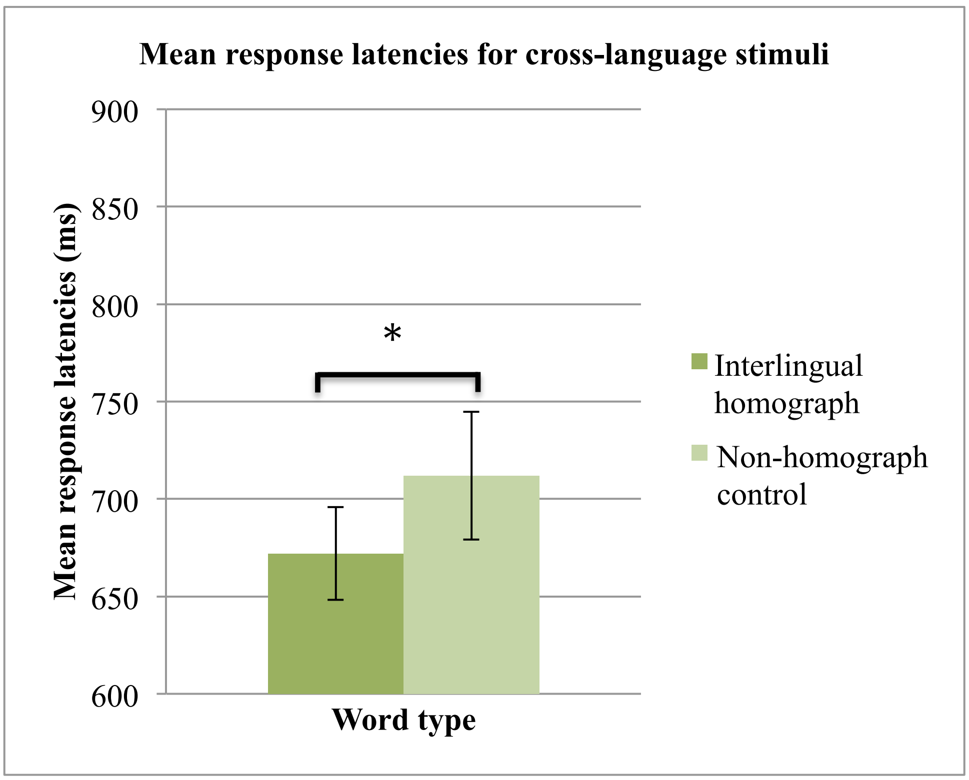

Figure **4-3**: Mean response latencies for the cross-language stimuli in the generalized lexical decision task in Experiment 2.

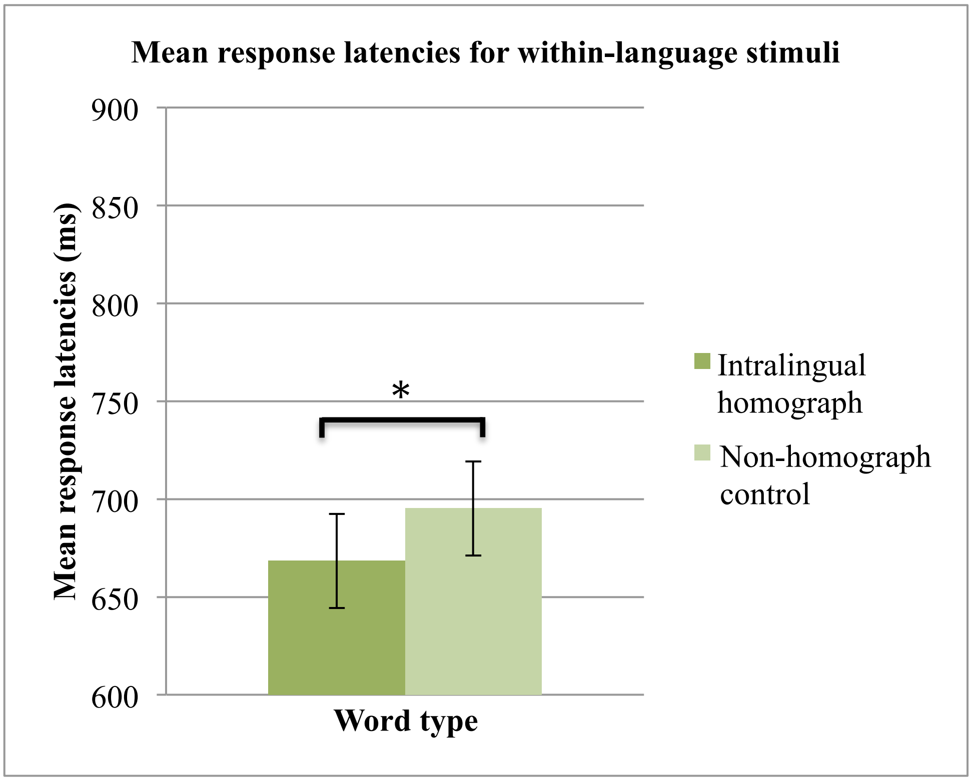

Figure **4-4**: Mean response latencies for the within-language stimuli in the generalized lexical decision task in Experiment 2.

Bilingual performance on the English and generalized lexical decision tasks

To examine cross- and within-language conflict across language-specific and non-specific contexts, bilingual response latency data from across the English and generalized lexical decision tasks were analyzed by conducting 2 ANOVAs. A 2 task (English vs. generalized) x 2 cross-language stimuli (interlingual homograph vs. control) ANOVA with subjects (F1) and items (F2) as random factors was conducted. A 2 task (English vs. generalized) x 2 within-language stimuli (intralingual homograph vs. control) ANOVA with subjects (F1) and items (F2) as random factors was also conducted.

The main effect of task for the bilingual response latency data from the English and generalized lexical decision tasks was significant ($F1(1,19) = 26.083$, $p<.001$, $F2(1,70) = 86.800$, $p<.001$); stimuli from the English lexical decision task (M=783 ms; SD=142) were recognized 91 ms slower than stimuli from the generalized lexical decision task (M=692 ms; SD=128). The main effect of cross-language stimuli was not significant ($F1(1,19) = 2.617$, $p=.122$, $F2(1,70) = .335$, $p=.565$). The interaction between task and cross-language stimuli was marginally significant ($F1(1,19) = 3.837$, $p=.065$, $F2(1,70) = 2.780$, $p=.100$). Interlingual homographs (M=782 ms; SD=136) were recognized 2 ms faster than the non-homograph controls (M=784 ms; SD=151) in the English lexical decision task. Interlingual homographs (M=672 ms, SD=106) were recognized 40 ms faster than the non-homograph controls (M=712 ms, SD=147) in the generalized lexical decision task. Mean response latencies are shown in Figure 4-5.

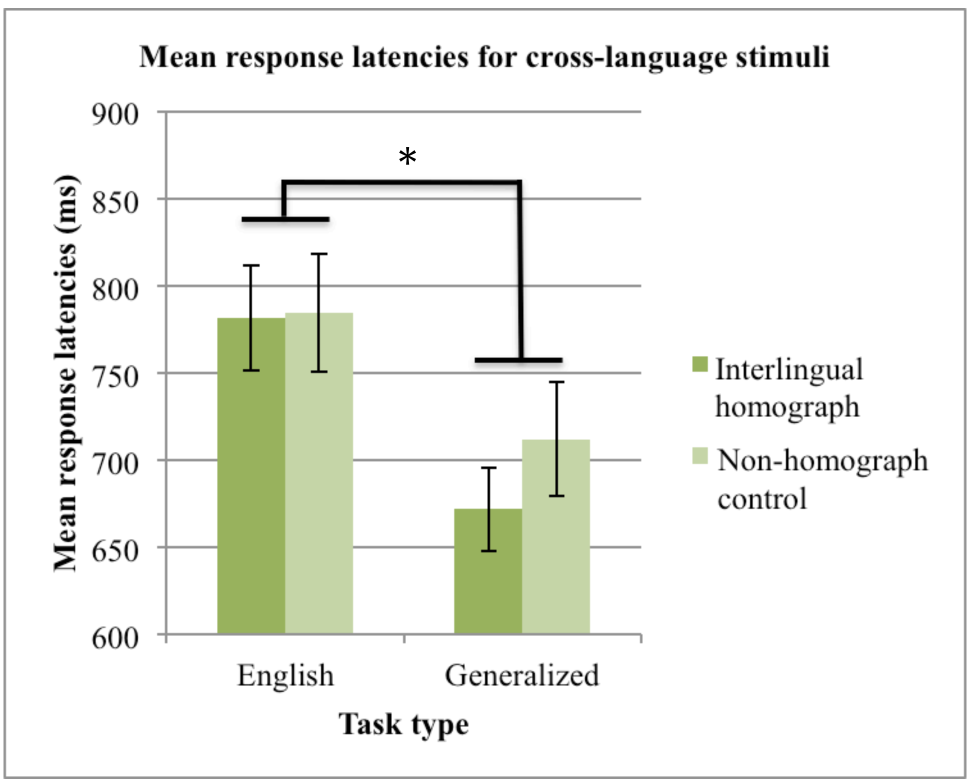

Figure **4-5**: Mean response latencies for the cross-language stimuli across the lexical decision tasks in Experiment 2.

The main effect of task for the bilingual response latency data from the English and generalized lexical decision tasks was significant ($F1(1,19) = 16.148$, $p=.001$, $F2(1,70) = 79.217$, $p<.001$); stimuli from the English lexical decision task (M=761 ms; SD=140) were recognized 79 ms slower than stimuli from the generalized lexical decision task (M=682 ms; SD=107). The main effect of within-language stimuli was significant in the by-subject analysis, but not in the by-item analysis ($F1(1,19) = 18.373$, $p<.001$, $F2(1,70) = 1.957$, $p=.166$); intralingual homographs (M=708 ms; SD=132) were recognized 27 ms faster than non-homograph controls (M=735 ms; SD=128). The interaction between task and within-language stimuli was not significant ($F1(1,19) = .001$, $p=.979$, $F2(1,70) = .047$, $p=.830$). Mean response latencies are shown in Figure 4-6.

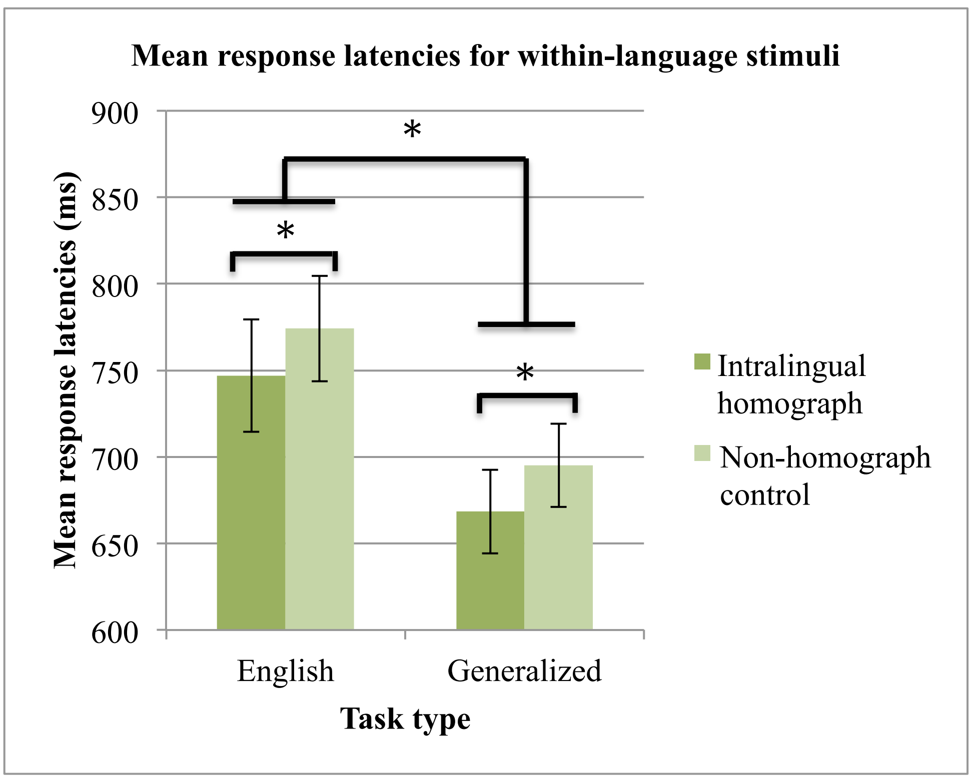

Figure **4-6**: Mean response latencies for the within-language stimuli across the lexical decision tasks in Experiment 2.

Cued color-shape task

To examine non-linguistic conflict, data from the cued-color shape task were analyzed by conducting two one-factor repeated measures ANOVAs. A 2 trial type (switch vs. non-switch) ANOVA on response latency with subjects (F1) as random factors was conducted. A 2 trial type (switch vs. non-switch) ANOVA on response accuracy with subjects (F1) as random factors was also conducted.

In the cued color-shape task, the main effect of trial type was significant ($F1(1,19) = 34.869$, $p<.001$); switch trials ($M=793$ ms; $SD=35$) were recognized 44 ms slower than non-switch trials ($M=749$ ms; $SD=47$). The main effect of trial type on accuracy was also significant ($F1(1,19) = 25.239$, $p<.001$); switch trials ($M=64$; $SD=14$) were recognized 10% less accurately than non-switch trials ($M=74$; $SD=10$). Mean response latencies and accuracies are shown in Figures 4-7 and 4-8, respectively.

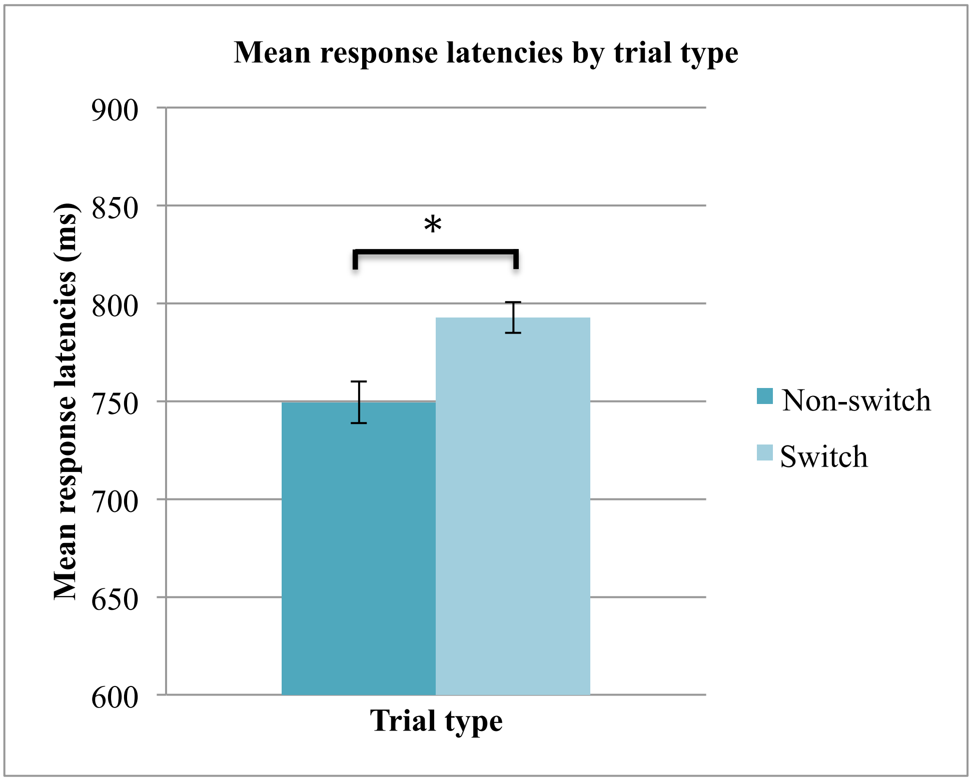

Figure **4-7**: Mean response latencies for the cued color-shape task in Experiment 2.

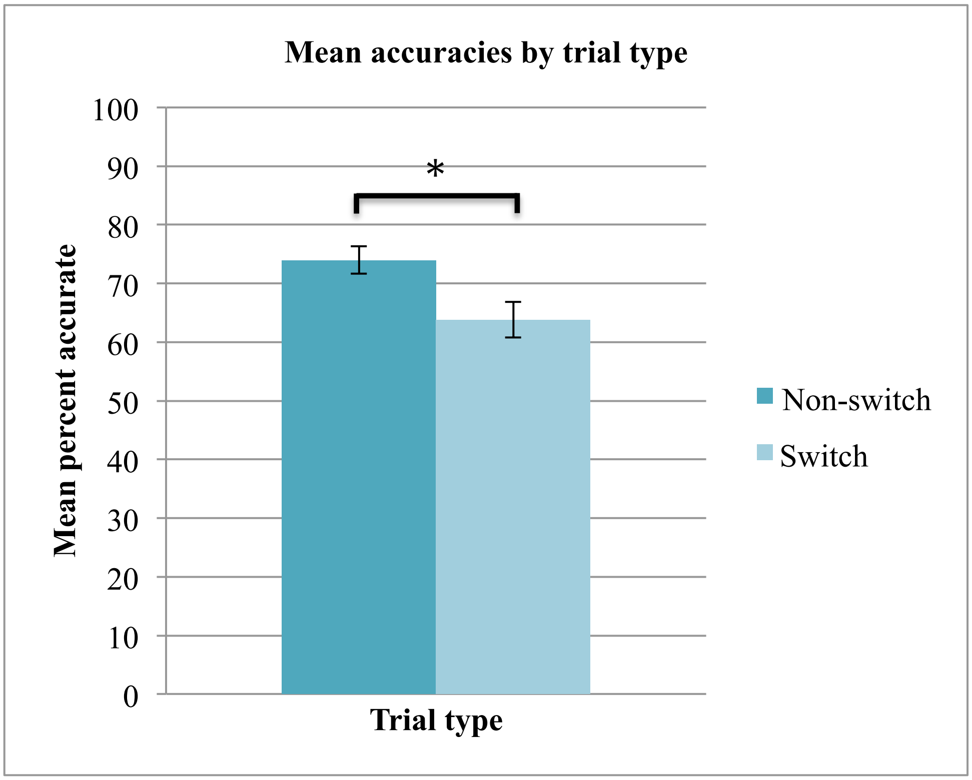

Figure **4-8**: Mean accuracies for the cued color-shape task in Experiment 2.

Correlational analyses

We performed a correlational analysis on response latency data in the same manner as in Experiment 1 in order to combine performance on the linguistic and non-linguistic conflict tasks.

For the English lexical decision task, the correlation between the interlingual homograph effect and the switch effect was not significant (r(20) = -.301, p = .198). The correlation between the intralingual homograph effect and the switch effect was not significant either (r(20) = .101, p = .672).

For the generalized lexical decision task, the correlation between the interlingual homograph effect and the switch effect was not significant (r(20) = .039, p = .869). The correlation between the intralingual homograph effect and the switch effect was also not significant ($r(20) = .036$, $p = .882$).

Cognitive measures

The Operation Span score and Flanker Effect are calculated in the same manner as in Experiment 1. The mean O-Span score was 42.7 (SD=7.1) out of 60. The mean Flanker effect was 57.9 ms (SD=27.1). To explore to what extent these scores differed from the monolingual participants tested in Experiment 1, t-tests were conducted. The mean O-Span scores of the Spanish-English bilinguals were slightly worse than those of the monolinguals, with Spanish-English bilinguals (M=42.4, SD=7.1) scoring 5.1 lower than English monolinguals (M=47.5, SD=4.3). The Flanker effect of the Spanish-English bilinguals was no different than that of the English monolinguals ($t(40) = .978$, $p=.334$).

Discussion

The Spanish-English bilinguals showed a significant facilitation effect only for the intralingual homographs in the English lexical decision task, but not in the interlingual homographs. In the generalized lexical decision task, there was significant interlingual and intralingual facilitation. Response latencies were again generally slower for the English task than the generalized task, indicating that task instruction affects processing time even for bilinguals who are being tested in their second language (English). These findings suggest that the language of instruction in language-specific lexical decision tasks affects interlingual homograph processing.

In the cued color-shape task, there was a significant switch cost for response latency and accuracy. There was no significant correlation between the homograph effects in either the English or generalized lexical decision task and the switch effect. These findings again suggest that there is no direct relationship between the cognitive mechanisms used to resolve the linguistic and non-linguistic conflict examined in this experiment.

Overall analyses

In order to answer whether bilinguals with different first languages process interlingual conflict similarly or differently, bilingual response latency data from the English and generalized lexical decision tasks were analyzed by conducting two overall ANOVAs. A 2 first language (English vs. Spanish) x 2 task (English vs. generalized) x 2 cross-language stimuli (homograph vs. control) ANOVA with subjects (F1) and items (F2) as random factors was conducted. In the present and subsequent by-subject analysis, language was treated as a between-subjects variable and stimuli and task were treated as within-subject variables. In the by-item analysis, language and task were treated as within-subjects variables and stimuli as treated as a between-subject variable.

The main effect of first language was significant ($F1(1,40) = 16.836$, $p<.001$, $F2(1,70) = 247.587$, $p<.001$); English-Spanish bilinguals (M=592 ms; SD=115) recognized cross-language stimuli 146 ms faster than Spanish-English bilinguals (M=738 ms; SD=142). The main effect of task was significant ($F1(1,40) = 23.870$, $p<.001$, $F2(1,70) = 74.670$, $p<.001$); stimuli from the English lexical decision task (M=697 ms; SD=162) were recognized 64 ms slower than stimuli from the generalized lexical decision task (M=633 ms; SD=125). The main effect of cross-language stimuli was significant in the by-subject analysis, but not the item analysis ($F1(1,40) = 4.170$, $p=.048$, $F2(1,70) = .265$, $p=.608$); interlingual homographs (M=657 ms; SD=141) were recognized 15 ms faster than non-homograph controls (M=672 ms; SD=154). The 3-way interaction between first language, task, and cross-language stimuli was significant ($F1(1,40) = 4.160$, $p=.048$, $F2(1,70) = 5.403$, $p=.023$), driven by a significant interaction between first language and task ($F1(1,40) = 4.465$, $p=.041$, $F2(1,70) = 29.990$, $p<.001$). English-Spanish bilinguals (M=610 ms; SD=134) recognized cross-language stimuli in the English lexical decision task 37 ms slower as compared to in the generalized lexical decision task (M=573 ms; SD=91). Meanwhile, Spanish-English bilinguals recognized cross-language stimuli in the English lexical decision task (M=783 ms; SD=142) 91 ms slower as compared to in the generalized lexical decision task (M=692 ms; SD=128). The interaction between stimulus and first language was not significant ($F1(1,40) = .806$, $p=.375$, $F2(1,70) = .251$, $p=.618$), nor was the interaction between task and stimulus ($F1(1,40) = 1.566$, $p=.218$, $F2(1,70) = .482$, $p=.490$).

In order to answer whether bilinguals with different first languages process intralingual conflict similarly or differently, bilingual response latency data from the English and generalized lexical decision tasks were analyzed by conducting a 2 first language (English vs. Spanish) x 2 task (English vs. generalized) x 2 within-language stimuli (intralingual homograph vs. control) ANOVA with subjects (F1) and items (F2) as random factors.

The main effect of first language was significant ($F1(1,40) = 15.540$, $p<.001$, $F2(1,70) = 288.288$, $p<.001$); English-Spanish bilinguals (M=595 ms; SD=103) recognized within-language stimuli 126 ms faster than Spanish-English bilinguals (M=721 ms; SD=128). The main effect of task was significant ($F1(1,40) = 20.241$, $p<.001$, $F2(1,70) = 93.026$, $p<.001$); stimuli from the English lexical decision task (M=686 ms; SD=144) were recognized 56 ms slower than stimuli from the generalized lexical decision task (M=630 ms; SD=114). The main effect of within-language stimuli was significant in the by-subject analysis and marginally significant in the item analysis ($F1(1,40) = 54.066$, $p<.001$, $F2(1,70) = 3.571$, $p=.063$); intralingual homographs (M=642 ms; SD=133) were recognized 32 ms faster than non-homograph controls (M=674 ms; SD=131).

The 3-way interaction between first language, task, and within-language stimuli was not significant (F1(1,40) = .153, p=.698, F2(1,70) = .056, p=.813). The interaction between task and first language was marginally significant (F1(1,40) = 3.389, p=.073, F2(1,70) = 20.500, p<.001). The interaction between stimulus and first language was not significant (F1(1,40) = 1.518, p=.225, F2(1,70) = .094, p=.760), nor was the interaction between task and stimulus (F1(1,40) = .188, p=.667, F2(1,70) = .336, p=.564).

In order to answer whether speakers with different first languages process intralingual conflict similarly or differently, response latency data from the English lexical decision task were analyzed by conducting a 2 first language (English-Spanish bilingual and English monolingual vs. Spanish-English bilingual) x 2 within-language stimuli (intralingual homograph vs. control) ANOVA with subjects (F1) and items (F2) as random factors.

The main effect of first language was significant (F1(1,62) = 20.499, p<.001, F2(1,70) = 188.649, p<.001); English-Spanish bilinguals and English monolinguals (M=622 ms; SD=104) recognized within-language stimuli 139 ms faster than Spanish-English bilinguals (M=761 ms; SD=140). The main effect of within-language stimuli was significant in the by-subject analysis and marginally significant in the item analysis (F1(1,62) = 38.977, p<.001, F2(1,70) = 2.983, p=.089); intralingual homographs (M=647 ms; SD=134) were recognized 36 ms faster than non-homograph controls (M=683 ms; SD=130). The interaction between first language and within-language stimuli was not significant (F1(1,62) = 1.588, p<.212, F2(1,70) = .299, p=.587).

In order to answer whether bilinguals and monolinguals process intralingual conflict similarly or differently, response latency data from the English lexical decision task were analyzed by conducting a 2 speaker (English-Spanish and Spanish-English bilingual vs. English monolingual) x 2 within-language stimuli (intralingual homograph vs. control) ANOVA. The effect of speaker type trended toward significance in the by-subject analysis and was significant in the item analysis (F1(1,62) = 2.184, p<.145, F2(1,70) = 93.757, p<.001). The main effect of within-language stimuli was significant (F1(1,62) = 48.571, p<.001, F2(1,70) = 3.990, p=.050); intralingual homographs (M=647 ms; SD=134) were recognized 36 ms faster than non-homograph controls (M=683 ms; SD=130). The interaction between within-language stimuli and speaker type was not significant (F1(1,62) = .262, p<.611, F2(1,70) = 1.431, p=.236).

In order to answer whether speakers with different language backgrounds process non-linguistic conflict similarly or differently, behavioral data from the cued-color shape task were analyzed by conducting two 3 speaker (English monolingual vs. English-Spanish bilingual vs. Spanish-English bilingual) x 2 trial type (switch vs. non-switch) ANOVAs on response latency data and the accuracy data, treating speaker as a between-subject variable and trial type as a within-subject variable.

In the latency analysis, the main effect of trial type on response latency was significant (F1 (1,61) = 69.329, p<.001); switch trials (M=769 ms; SD=48) were recognized 35 ms slower than non-switch trials (M=734 ms; SD=50). The main effect of speaker was also significant (F1 (1,61) = 5.425, p=.007). English-Spanish bilinguals (M=728 ms; SD=56) recognized stimuli 28 ms faster than English monolinguals (M=756 ms; SD=44) who recognized stimuli 15 ms faster than Spanish-English bilinguals (M=771 ms; SD=47). A post-hoc test using Bonferroni correction revealed that the English monolinguals did not differ from the English-Spanish bilinguals (756 + 44 ms vs. 728 + 56) or the Spanish-English bilinguals (756 + 44 ms vs. 771 + 47). However, the English-Spanish and Spanish-English bilinguals (728 + 56 vs. 771 + 47) differed from each other. The interaction between trial type and speaker was not significant (F1 (1,61) = 1.529, p=.225).

In the accuracy analysis, the main effect of trial type was significant (F1 (1,61) = 87.042, p<.001); switch trials (M=64; SD=14) were recognized 9% less accurately than non-switch trials (M=75; SD=11). The main effect of speaker was not significant (F1(1,61) = .883, p=.419). The interaction between trial type and speaker was not significant (F1(1,61) = .282, p=.755).

Chapter 5

General Discussion

The present study sought to examine how bilingual speakers resolve conflict and use general cognitive control mechanisms in linguistic and non-linguistic contexts. The secondary goal was to examine whether monolinguals utilize these cognitive control mechanisms in the same manner as bilinguals. To answer these questions, we conducted two experiments. In Experiment 1, English-Spanish bilingual and English monolingual participants completed conflict tasks: a language-specific lexical decision task in their first language (English), a generalized lexical decision task (bilinguals only), and a non-linguistic cued color-shape task. In Experiment 2, Spanish-English bilingual participants completed the same conflict tasks, but the language-specific lexical decision task was in their second language (English).

Table **5-1**: Overview of findings from Experiments 1 and 2.

	English lexical decision task	
	Interlingual homographs	Intralingual homographs
English-Spanish bilinguals	facilitation*	facilitation
English monolinguals	facilitation*	facilitation
Spanish-English bilinguals	no effect	facilitation*
	Generalized lexical decision task	
	Interlingual homographs	Intralingual homographs
English-Spanish bilinguals	no effect	facilitation
Spanish-English bilinguals	facilitation#	facilitation#

	Cued color-shape task
English-Spanish bilinguals	switch cost
English monolinguals	switch cost
Spanish-English bilinguals	switch cost

* means significant in F1 analysis, p > .15 in F2 analysis;
# means significant in F1 analysis, .05 < p < .15 in F2 analysis

The findings of Experiments 1 and 2 are summarized in Table 6.1. In Experiment 1, English-Spanish bilingual speakers completed the language-specific lexical decision task in their first language where they were presented with interlingual and intralingual homographs and their item-matched controls, English fillers, and English non-words. In this task, the English-Spanish bilinguals showed an interlingual and an intralingual homograph facilitation effect. In the generalized lexical decision task, however, the English-Spanish bilinguals did not show an interlingual homograph effect, but they did show a facilitatory intralingual homograph effect. English monolingual speakers (who only completed the language-specific lexical decision task) showed a facilitatory effect for both interlingual and intralingual homograph processing. In the non-linguistic cued color-shape task, the bilingual and monolingual speakers performed similarly and both experienced a switch cost, such that they responded less quickly and less accurately after switch trials as compared to non-switch trials.

In Experiment 2, Spanish-English bilingual speakers completed the language-specific lexical decision task in their second language and only showed an intralingual facilitation effect. Interestingly, in the generalized lexical decision task, they showed an interlingual facilitation effect and an intralingual facilitation effect. In the cued color-shape task, the bilingual speakers in Experiment 2 showed the same switch effect that was discussed earlier.

With respect to our primary research goal, overall analyses suggest that bilinguals and monolinguals alike rely on similar cognitive mechanisms in the linguistic and non-linguistic tasks. Bilinguals performed similarly to monolinguals on the cued color-shape task and did not show a measurable advantage at resolving non-linguistic conflict as a result of their experience managing their two languages. Both monolinguals and bilinguals experienced intralingual homograph facilitation in the English lexical decision task. Moreover, speakers with different first languages (English vs. Spanish) all experienced intralingual homograph facilitation, although native English speakers did recognize stimuli more quickly than native Spanish speakers in the English lexical decision task.

The pattern of response latency data for interlingual homograph processing in the present study is not what the BIA+ or Inhibitory Control models predict. The BIA+ model (Dijkstra & Van Heuven, 2002) predicts that an interlingual homograph's semantic codes should compete, resulting in exaggerated response latencies. The Inhibitory Control model (Green, 1998) predicts this effect to be particularly pronounced when participants process homographs in their second language due to competition from the concurrently activated first language, especially when participants are dominant in their first language. Moreover, a response- and stimulus-based account of linguistic conflict (Van Heuven et al., 2008) predicts for competition to occur in the language-specific lexical decision tasks and not the generalized lexical decision tasks, because the response-based conflict posed by recognizing an interlingual homograph with respect to one language requires additional processing time. Instead, we observed that interlingual homographs are recognized just as quickly, or even faster, than the non-homograph matched controls in the English specific lexical decision task. Moreover, we observed that Spanish-English participants utilize a homograph's dual representations in a generalized lexical decision task to facilitate homograph recognition, so that they recognize homographs more quickly than the matched controls.

We explored two alternative explanations for the absence of an interlingual interference effect in the present study. First, we investigated whether an interlingual homograph's lexical frequencies across languages were affecting the bilinguals' response latencies. If a homograph's lexical frequencies interact with homograph processing, then we would expect to observe an effect of stimulus type on response latency. In particular, we would expect for English-Spanish bilinguals to process homographs with high English and low Spanish frequencies faster than the item-matched controls, whereas Spanish-English bilinguals would process homographs with low English and high Spanish frequencies faster than the item-matched controls. Meanwhile, if there is no interaction between a homograph's lexical frequencies and response latencies, then we would expect for both homographs with high English and low Spanish frequencies and homographs with low English and high Spanish frequencies to be processed as quickly as the item-matched controls for both English-Spanish and Spanish-English bilinguals. Analyses on the response latencies did not show a consistent main effect of high English and low Spanish stimuli or low English and high Spanish stimuli on response latency data in either the English or generalized lexical decision task (see Appendix B for more details and the full report of the statistical analyses). Only in the generalized lexical decision task performed by Spanish-English bilinguals was there a significant effect ($F1(1,21) = 6.773$, $p=.017$, $F2(1,10) = .209$, $p=.657$), where Spanish-English bilinguals recognized homographs with high English and low Spanish frequencies ($M=655$, $SD= 108$) 115 ms faster than their item-matched controls ($M=770$, $SD= 224$). This pattern of findings suggests that differences in cross-language lexical frequency cannot fully explain the absence of interlingual homograph interference effects.

A second hypothesis that we explored was whether an interlingual homograph's phonological overlap across languages was affecting the bilinguals' response latencies. If the amount of phonological overlap in the Spanish and English forms of an interlingual homograph affects processing, then we would expect homographs with high phonological overlap to be recognized more quickly than their item-matched controls, because the phonological overlap would result in strong language co-activation. However, if phonological overlap does not affect homograph processing, then we would expect there to be no difference in processing times for homographs with high or low phonological overlap as compared to the item-matched control words. Analyses on the response latencies of the English-Spanish and Spanish-English bilinguals did not show a consistent main effect for stimuli with high phonological overlap in the response latency data in either the English or generalized lexical decision task (see Appendix C for more details and the full report of the statistical analyses). Of the eight ANOVAs, one significant facilitation effect was observed for the high-overlap items, and two significant facilitation effects were observed for the low-overlap items. The remaining 5 ANOVAs did not yield significant effects. This pattern of findings suggests that differences in cross-language phonological overlap cannot explain the absence of interlingual homograph interference effects.

A third hypothesis we explored was whether variation in an intralingual homograph's semantic overlap within languages was affecting bilinguals and monolinguals' response latencies. Previous literature suggests that processing times for intralingual homographs depend on whether the homograph's meanings are related or not, where a homograph with unrelated meanings (low overlap) is recognized more slowly than matched controls (Klepousniotou & Baum, 2007; Rodd, Gaskell, & Marslen-Wilson, 2002). In order to test how and whether the semantic overlap in our intralingual stimuli affects homograph processing, we obtained ratings of the intralingual homograph's semantic overlap (see Appendix D for more details), and classified the homographs as having either high (n = 10) or low (n = 26) semantic overlap. ANOVAs comparing homographs with low semantic overlap to their matched controls and ANOVAs comparing homographs with highly related meanings to their matched controls did not show a consistent pattern (see Appendix B for more details and the full report of the statistical analyses). The six ANOVAs on the English lexical decision data of the monolinguals and the bilinguals showed faster processing times on the low overlap homographs relative to controls (in three analyses), slower processing on the high overlap items relative to control (in one analysis) and no significant differences (in two analyses). This pattern of findings suggests that variation in semantic overlap in the intralingual homographs cannot fully explain the intralingual homograph facilitation. If anything, the outcomes of these post-hoc analyses differ from the earlier studies in that homographs with low overlap in meanings were recognized faster (instead of slower) than item-matched controls.

As discussed above, our findings do not replicate the interlingual homograph interference effect reported in Dijkstra et al. (1998) and Van Heuven et al. (2008) and seem difficult to reconcile with models assuming lexical competition (e.g., the BIA+ model). However, an account based on a horse race model can potentially explain the absence of interference in the language-specific lexical decision task in bilinguals who conducted this task in their L1. According to the horse race model, lexical candidates of the bilingual's two languages are activated upon seeing a homograph and the latency to recognize a word is determined by which of the two parallel routes finishes faster. If the bilingual is more proficient in the L1, the L1 homograph form is selected earlier than the L2 homograph form and the homograph is identified as an existing word before the L2 homograph's meaning becomes active and can compete with the L1 homograph's meaning. Hence, no competition occurs and the homograph can in fact be recognized earlier than the non-homograph control because of cross-language orthographic overlap in the initial stage of lexical access. For a language-specific lexical decision task in the L2, in highly proficient L2 speakers, such as the ones tested in the present study, a similar parallel-routes model can explain the present findings (no homograph interference effect) by assuming that recognition of the L2 homograph reading has been largely completed before competition of the L1 homograph meaning enters the decision process. Finally, for interlingual homographs in the generalized lexical decision task, this horse race interpretation (as well as the BIA+ model) also predicts no semantic competition, because the task instructions eliminate response-based language selection.

In the English and generalized lexical decision tasks, we observed a consistent facilitatory effect for intralingual homographs. Both bilinguals and monolinguals processed these homographs more quickly than matched controls and this effect was present regardless of the speaker's first language. This pattern of findings suggests that homograph processing does not necessarily result in semantic competition, and seems more in line with horse-race based models than with competition-based models.

In the final section of the General Discussion, we turn to the non-linguistic task. According to the Inhibitory Control model, bilinguals rely on a domain-general cognitive mechanism to manage their two languages (Green, 1998). Given then that a bilingual has heightened practice using cognitive control, recent studies have sought to test whether bilinguals are better at resolving non-linguistic conflict as compared to monolinguals (e.g., Bialystok, Craik, & Luk, 2008; Costa, Hernández, & Sebastián-Gallés, 2008). Indeed, a bilingual advantage has been observed in both bilingual children (e.g., Bialystok & Martin, 2004; Martin-Rhee & Bialystok, 2008; Poarch & Van Hell, 2012) and older adults (e.g., Bialystok, Craik, Klein, & Viswanathan, 2004; Bialystok, Craik, & Luk, 2008; Bialystok, Craik, & Ryan, 2006).

Data from the cued color-shape task showed switching costs for both groups of bilinguals and the monolinguals, and the magnitude of the switch costs of two groups of bilingual speakers did not differ from that of the monolingual speakers. Because of this pattern of findings, we cannot conclude that bilingual speakers have an advantage at resolving non-linguistic conflict as compared to monolinguals. Moreover, the analyses correlating the bilinguals' and monolinguals' performance on the linguistic and non-linguistic conflict tasks (lexical decision tasks and the cued color-shape task) and the cognitive control measures (O-Span and Flanker) demonstrated that the performance of the bilingual speakers was not different (better) from that of the monolingual speakers. While the previous data are inconclusive as to whether a direct relationship exists between linguistic and non-linguistic conflict resolution (e.g., Prior & MacWhinney, 2010; Prior & Gollan, 2011; Yim & Bialystok, 2012; Weissberger, Wierenga, Bondi, & Gollan, 2012), our findings suggest there is no direct relationship between these processes.

In conclusion, the results from the lexical decision tasks show that co-activation occurs across and within languages for bilinguals and monolinguals during word recognition, but the overwhelming finding of homograph facilitation rather than interference suggests that homograph processing does not always result in semantic competition. Moreover, in our groups of young adult speakers, neither English-Spanish nor Spanish-English bilinguals demonstrated an advantage at resolving non-linguistic conflict relative to monolingual peers. Instead, bilingual and monolingual speakers alike suffered from a switch cost in response latency and accuracy.

Chapter 6

Future directions

In Chapter 1, we discussed the findings from Van Heuven et al.'s (2008) study on cross-language interference caused by homographs and Garbin et al.'s (2010) study on non-linguistic conflict caused by task-switching. Both studies used behavioral and fMRI techniques methodologies in order to answer their research questions. Overall, the Van Heuven et al. and the Garbin et al. studies observed activation in areas that overlap with those posited in the cortical-subcortical language control network proposed to complement the Inhibitory Control model (Abutalebi & Green, 2008). There are five regions identified in this neural network: left dorsolateral prefrontal cortex, the anterior cingulate cortex, the caudate nucleus, and bilateral supramarginal gyri. The prefrontal cortex is involved with executive functioning, including response inhibition, and works together with the anterior cingulate cortex to detect conflict. The caudate nucleus has been implicated in motor control and cognitive sequence planning and the bilateral supramarginal gyri in working memory and implementation and maintenance of task schema. Collectively, these regions form a subcortical-cortical network with regions that have been implicated in higher cognitive functioning.

In addition to Van Heuven et al. (2008) and Garbin et al. (2010), Stein et al. (2009) also reported imaging data in support of this network. Stein and colleagues used fMRI to investigate how second language lexical-semantic processing develops as second language proficiency increases. Native English speaking exchange students in Germany were asked to read words in English, German, and a third, unknown language (Romansh) in two different testing sessions. The first testing session was completed within the first two months of their stay and the second testing session was completed between four and seven months later.

Stein et al. expected to see heightened activity in frontal regions of the brain in relation to second language use, including the frontal regions identified in Abutalebi and Green (2008), reflecting the fact that use of the second language is more difficult than use of their first language and that it requires additional neural activity for successful performance. Furthermore, they expected for this heightened activity to decrease as a function of increased second language proficiency, such that the second language lexical-processing systems would begin to look more like the first language lexical-processing systems. In support of their hypotheses, in the second testing session, with an increase in second language proficiency, Stein et al. found a decrease in activation in frontal regions of the brain. Indeed, frontal activity that is initially required for successful second language use diminishes with prolonged experience, resulting in a second language lexical-semantic processing system that recruits on more similar neural correlates to that of the first language's.

Luk, Green, Abutalebi, and Grady (2012) recently performed a quantitative meta-analysis to test Abutalebi and Green's proposed bilingual language control network. The analysis was performed on ten language-switching studies that employed either positron emission technology or fMRI methodology. Multiple language pairings were included in order to increase generalizability of the concluding data. Ten distinct clusters of 100 mm3 minimum were identified after using a more conservative version of BrainMap's GingerALE algorithm (Lancaster et al., 2007). These clusters were mainly lateralized to the left hemisphere and were concentrated in frontal regions. The only activation that overlapped with Abutalebi and Green's (2008) model was in the caudate and left prefrontal cortex. Luk and colleagues did not observe significant activation in the anterior cingulate cortex. While this finding is surprising and contrary to Abutalebi and Green's model, it is in line with Stein et al.'s proposal. If baseline and language switching conditions involved error monitoring, then there should be no statistically significant difference in anterior cingulate cortex activity by condition. Furthermore, the meta-analysis identified three regions that were not in Abutalebi and Green's (2008) model: right precentral gyrus and bilateral temporal gyri. While the right precentral gyrus has been previously implicated in switching between task demands in picture naming (Nakamura et al., 2010), the temporal gyri have been associated with different functions depending on its lateralization (Sabri et al., 2008). The contribution of these regions' activation in bilingual language switching is yet to be determined.

Neuroimaging has also been used to study the neural correlates recruited during more purely non-linguistic conflict tasks. Simmonds, Pekar, and Mostofsky (2008) performed a meta-analysis on functional neuroimaging go/no-go tasks. Go/no go tasks employ a paradigm that allows for examination of response selection and inhibition as a means of resolving response-based conflict, under conditions in which other cognitive and behavioral processes are minimized. In a go/no go task, participants are asked to respond in indicated trials but withhold from response making in other trials. In a sense, the neural and cognitive mechanisms underlying performance on the go/no go task potentially provide insight on whether the neural correlates involved in non-linguistic response-based conflict and inhibition are the same as those used in response-based conflict and inhibition in language context.

Using the Activation Likelihood Estimate (ALE) (Turkeltaub et al., 2002), analyses confirm that in the context of a non-linguistic go/no-go task the inhibition recruited to resolve response-based conflict is associated mainly with a right-lateralized network. Specifically, the regions within this network are associated processes necessary for successful response-based conflict resolution: stimulus recognition, maintenance and manipulation of stimulus-response associations, as well as response selection. The ALE meta-analysis also revealed an effect of task difficulty on neural activation. In particular, in accordance with a previous meta-analysis (Buchsbaum et al., 2005), go/no-go tasks that contained more than one type of no-go cue relied on the working memory for successful manipulation of information showed increased activation in regions including the middle and inferior frontal gyrus, inferior parietal lobule, posterior cortical regions, and the prefrontal cortex. It is possible that these regions are recruited in response to increased working memory demands.

In the future, we aim to translate the linguistic and non-linguistic tasks from the present study to be conducted using a combination of behavioral and neuroimaging methodologies to explore to what extent the neural structures engaged in processing homographs and non-homograph controls in the first language overlap with those structures engaged in processing homographs and non-homograph controls in the second language, as well as to explore to what extent the neural structures engaged in homograph processing overlap with those structures engaged in non-linguistic conflict resolution. While neuroimaging has been used to examine the neural correlates involved in processing homographs and non-homograph controls in the second language (e.g., Van Heuven et al., 2008), no neuroimaging study has presented words in the first language. Thus, the neural correlates of processing homographs and non-homographs in the first language are yet to be determined.

In the future, we will also consider administering the linguistic and non-linguistic conflict tasks in order to examine the differences between bilinguals with high and low proficiency in their second language. Such a study can help to highlight factors that translate to successful second language acquisition. Moreover, neuroimaging could help inform the existing literature on the effect of second language knowledge on neural circuitry. For example, if differences in mastery of one's second language varies with cognitive processes and recruitment of neural control networks, it is feasible to expect for highly proficient bilinguals to perform like adult native speakers, while bilinguals with lower proficiency in their second language to perform more like younger native speakers (Luna & Sweeney, 2004). In order to study such an effect, a diffusion tensor imaging analysis may be conducted comparing monolinguals with high and low proficiency second language speakers. This analysis will reveal which fiber pathways structurally link brain regions to each other and which pathways are associated with the regions found to be critical in inhibitory control.

Appendix A

Linguistic Material

Interlingual homographs: actual agenda arena balloon bomber call cargo carpet casual choke collar curse dude embarrass eventual exit fin library mantel mayor media mess mole pan pie plate play realize rope sauce sensible soap tramp tuna vent voluble

Non-interlingual homograph matched controls: accurate amenity array bonnet burglar carrot chart coin cottage cotton curl current denim erratic excuse fit involve laughter maker manor mermaid meter milk pad pal plane plug remain roof scarf selfish shore tab trash valuable venue

Intralingual homographs: bolt brush calf canvas cast charge chest court cricket crooked dash deck digest dough draft dumb glass grain knot litter medallion mint pitch pound ruler screen seal slip sole speaker spell spring squash stick story suit

Non-intralingual homograph matched controls: bird broccoli carver chant chin crack cross curd curfew curry daddy damaged dancer diameter dorm drizzle glove groin knife lawn marrow maturity party poof sadness scare scout sir slime sod span speed spout stanza steel wrench

Fillers: ablaze abuse ache alarm aloud angst answer apple armpit auction available backing bandage barrage basil basket board boy buy cabbage cage candle candy cap careful cash cattle cell cellar chair cherry chore clean climber closet cloth clumsy coin cow deceit decoy dirt display dog door dust earl earnest eighty eleventh emphasize entitle eye fad farm flint fluff hair happy hot hurt ice illness lesson liability light maiden mailbox making male mallard match mattress maze meat mercy milk miller monkey mop moth movie name napkin nut oven pad pain painting patch pea pest pillow place plea ploy pocket poke quiet quiz raid rain rake reach regret relief revenue river sash scarce scent scheme scissors seed shirt shoe skirt sleepy soft speech spoon steady storm straight sun table tack tailor tape teacher tee three tool vault vest vicarious voiced wall warm wash wink worm yell

Non-words: acatement ander ary avainst baping barled beace beek beform beght begue belded benial bickle bimply biving blaced blere boofed bovers buring canced canked cathology ceared chading clated clight collily commemative commistely compended concesely conclutely conctically condicient congrate consible consulmation contility contion contrating coster cotion couck cour craced crayed dained danged dast dather deat deaver decame dectory dejution dession destle detter deveral discinative distable distription doiled doming dought drossed durner effection excent exchased exciation exclure exctatite expeciated fainty faling faming fanish fashed fazy firee firls flotered foared fobble focket fopped forned fortanely fotted frose frund fuddle gaided garistion gastle gearer gettle giding ginner gither glawed glight goney gooted gotter goveration grawn gressure grought haddle hallet hearly helled helt hiddle higger hilled hillow hingle hir hunder hunner hurther infaid infaticated inflative insent insposed introacted jopped jucked judgerent kint kintle kucker labble laly lant laring larrow lasked latted lattle leace learer lettle licket lingle liny lising lising lobble loring louged mave meach miness mobble morked mosing moting muke namper nangle narred nather nativery nattle nilled nitter nottle noving oncluded paller pangle parstice pasten peans pellow pettle pinished pinted posiness preastive preated pribed prined pritching progrest protage prought psychiation quind radder ralled rangle rapicer raturns realth rearful reasts refucition relder resuld rining risely roined ropper rulled sanner sasy sectowed sence sence sepention sevising shere shinge shoked shood siddle sigger sinistion sithout socian sody soliety soving stothed strang strest strindy strustion stupition succension suddle suggers sutted suzzle suzzle tacket tained tane tarked tarrow tasked tearer tefore thash thay thealed thearer theed ther thern thice thich thince thinge thowed thruping tifted tonest tuddle tuller tustle unimal univelled vagered vaking vamper vanker viscution volder waith whe whem whice whick

Appendix B

Examining how and whether an interlingual homograph's lexical frequencies affect homograph processing

In order to test how and whether a homograph's lexical frequencies interacts with homograph processing, we first obtained the lexical frequencies per million for each homograph's representation in English and Spanish using the CELEX database (Baayen, Piepenbrock, & van Rijn, 1993) and the corpora collected by Alameda and Cuentos (1995). Afterward, we performed a median split on these frequencies by language in order to identify which of homographs were English dominant and which were Spanish dominant in their frequencies. Of the 36 interlingual homographs, 21 had about equal frequencies. We identified six High-English, Low-Spanish (HE-LS) homographs to compare against their item-matched controls and nine Low-English, High-Spanish (LE-HS) homographs to compare against their item-matched controls. If a homograph's lexical frequencies interact with homograph processing, we would expect for English-Spanish bilinguals to process HE-LS homographs more quickly than the item-matched controls, whereas Spanish-English bilinguals would process LE-HS homographs more quickly than the item-matched controls. Meanwhile, if there is no interaction between a homograph's lexical frequencies and response latencies, then we would expect for both HE-LS and LE-HS homographs to be processed as quickly as their item-matched controls for both English-Spanish and Spanish-English bilinguals.

English-Spanish bilingual response latency data from the English lexical decision task were analyzed by conducting two one-factor stimuli (homograph vs. control) ANOVAs with subjects (F1) and items (F2). The main effect of HE-LS stimuli was not significant ($F1(1,21)$ =

.008, p=.928, F2(1,10) = .004, p=.953). The main effect of LE-HS stimuli was also not significant (F1(1,21) = .430, p=.521, F2(1,16) = .088, p=.771).

A similar ANOVA was used to analyze the Spanish-English bilingual response latency data of the English lexical decision task. The main effect of HE-LS stimuli trended toward significance in the by-participant analysis, but not in the by-item analysis (F1(1,21) = 2.925, p=.103, F2(1,10) = .522, p=.487). The main effect of LE-HS stimuli was not significant (F1(1,21) = .771, p=.391, F2(1,16) = .032, p=.861).

The ANOVA on the English-Spanish bilingual response latency data of the generalized lexical decision task showed that the main effect of HE-LS stimuli was not significant (F1(1,21) = .077, p=.785, F2(1,10) = .074, p=.791). The main effect of LE-HS stimuli was marginally significant in the by-participant analysis, but not in the by-item analysis (F1(1,21) = 3.400, p=.079, F2(1,16) = .816, p=.380).

Spanish-English bilingual response latency data from the generalized lexical decision task showed that the main effect of HE-LS stimuli was significant in the by-participant analysis, but not in the by-item analysis (F1(1,21) = 6.773, p=.017, F2(1,10) = .209, p=.657); HE-LS homographs (M=655, SD= 108) were recognized 115 ms faster than their item-matched controls (M=770, SD= 224). The main effect of LE-HS stimuli was not significant (F1(1,21) = .366, p=.552, F2(1,16) = .242, p=.630).

Appendix C

Examining how and whether an interlingual homograph's phonological overlap affects homograph processing

In order to test how and whether a homograph's phonological overlap affects homograph processing, we first obtained ratings of the interlingual homograph's phonological overlap. Nine English-Spanish bilingual and ten Spanish-English bilingual speakers provided these ratings after they completed the experiment. Participants were presented visually with the homograph pairs (e.g., arena/arena) and asked to rate how phonologically similar or different they perceived the pairs on a scale of 1 (completely unrelated) to 7 (completely related). We classified the homograph pairs as having either high or low phonological overlap based on whether their average rating by speaker group was above or below 3.5. Of the 36 homographs, we identified eighteen homographs with high phonological overlap to compare against their item-matched controls and six homographs with low phonological overlap to compare against their item-matched controls. If an interlingual homograph with high phonological overlap were affected by its phonology, then we would expect for these homographs to be processed more quickly as compared to controls, because the phonological overlap would result in strong language co-activation. However, if phonology does not affect homograph processing, then we would expect there to be no difference in processing times for homographs with high overlap as compared to homographs with low overlap.

English-Spanish bilingual response latency data from the English lexical decision task were analyzed by conducting two one-factor stimuli (homograph vs. control) ANOVAs with subjects (F1) and items (F2). The main effect of stimuli with high phonological overlap was significant in the by-participant analysis and trended toward significance in the by-item analysis ($F1(1,21) = .008$, $p=.011$, $F2(1,34) = 2.463$, $p=.126$); homographs with high phonological overlap

(M=619, SD= 158) were recognized 36 ms faster than their item-matched controls (M=655, SD= 150). The main effect of stimuli with low phonological overlap was not significant ($F1(1,21) = 1.540$, $p=.231$, $F2(1,10) = .153$, $p=.704$).

Spanish-English bilingual response latency data from the English lexical decision task were analyzed using the same one-factor ANOVAs. The main effect of stimuli with high phonological overlap was not significant ($F1(1,21) = .967$, $p=.338$, $F2(1,34) = .293$, $p=.592$). The main effect of stimuli with low phonological overlap was significant in the by-participant analysis, but not in the by-item analysis ($F1(1,21) = 16.451$, $p<.001$, $F2(1,10) = .016$, $p=.901$); homographs with low phonological overlap (M=711, SD= 96) were recognized 134 ms faster than their item-matched controls (M=845, SD= 177).

English-Spanish bilingual response latency data from the generalized lexical decision task were analyzed by conducting two one-factor ANOVAs. The main effect of stimuli with high phonological overlap was not significant ($F1(1,21) = .849$, $p=.367$, $F2(1,34) = .317$, $p=.577$). The main effect of stimuli with low phonological overlap was not significant ($F1(1,21) = .732$, $p=.402$, $F2(1,10) = .088$, $p=.772$).

Spanish-English bilingual response latency data from the generalized lexical decision task were analyzed by conducting two one-factor ANOVAs. The main effect of stimuli with high phonological overlap was marginally significant in the by-participant analysis, but not in the by-item analysis ($F1(1,21) = 3.280$, $p=.086$, $F2(1,34) = 1.244$, $p=.272$). The main effect of stimuli with low phonological overlap was significant in the by-participant analysis, but not in the by-item analysis ($F1(1,21) = 23.600$, $p<.001$, $F2(1,10) = 2.076$, $p=.177$); homographs with low phonological overlap (M=652, SD= 110) were recognized 125 ms faster than their item-matched controls (M=777, SD= 185).

Appendix D

Examining how and whether an intralingual homograph's semantic overlap affects homograph processing

Previous literature has found that processing times for intralingual homographs appear to depend on whether the homograph's meanings are related or not, where a homograph with unrelated meanings (low semantic overlap) is recognized more slowly than matched controls (e.g., Klepousniotou & Baum, 2007; Rodd, Gaskell, & Marslen-Wilson, 2002). In order to test how and whether the semantic overlap in our intralingual stimuli affects homograph processing, we first obtained ratings of the intralingual homograph's semantic overlap. Thirteen native English speakers provided these ratings. They were presented visually with the set of intralingual homographs and asked to rate how semantically similar or different they perceived the homograph's meanings on a scale of 1 (completely unrelated) to 7 (completely related). We classified the homographs as having either high or low semantic overlap based on whether their average rating by speaker group was above or below 3.5. In the end, we isolated ten homographs with high semantic overlap to compare to their item-matched controls and twenty-six homographs with low semantic overlap to compare to their item-matched controls.

English monolingual response latency data from the English lexical decision task were analyzed by conducting two one-factor stimuli (homograph vs. control) ANOVAs with subjects (F1) and items (F2). The main effect of stimuli with high semantic overlap was significant in the by-participant analysis and trended toward significance in the by-item analysis ($F1(1,19) = 6.936$, $p=.014$, $F2(1,18) = 2.504$, $p=.131$); homographs with high semantic overlap ($M=696$, $SD= 114$) were recognized 55 ms slower than their item-matched controls ($M=641$, $SD= 118$). The main effect of stimuli with low semantic overlap was also significant ($F1(1,19) = 72.996$, $p<.001$,

$F2(1,50) = 13.758$, $p<.001$); homographs with low semantic overlap ($M=610$, $SD= 103$) were recognized 71 ms faster than their item-matched controls ($M=681$, $SD= 112$).

English-Spanish bilingual response latency data from the English lexical decision task were analyzed by conducting similar one-factor ANOVAs. The main effect of stimuli with high semantic overlap was not significant ($F1(1,21) = 1.747$, $p=.204$, $F2(1,18) = .138$, $p=.714$). The main effect of stimuli with low semantic overlap was significant ($F1(1,21) = 29.410$, $p<.001$, $F2(1,50) = 15.644$, $p<.001$); homographs with low semantic overlap ($M=588$, $SD= 119$) were recognized 59 ms faster than their item-matched controls ($M=647$, $SD= 117$).

Spanish-English bilingual response latency data from the English lexical decision task were analyzed by conducting similar one-factor ANOVAs. The main effect of stimuli with high semantic overlap was not significant ($F1(1,21) = .044$, $p=.836$, $F2(1,18) = .438$, $p=.516$). The main effect of stimuli with low semantic overlap was significant in the by-participant analysis and marginally significant in the by-item analysis ($F1(1,21) = 8.338$, $p=.009$, $F2(1,50) = 3.654$, $p=.062$); homographs with low semantic overlap ($M=770$, $SD= 144$) were recognized 40 ms faster than their item-matched controls ($M=810$, $SD= 137$).

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