Interhemispheric Communication: How do first and second languages interact?

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Abstract

How is it that a bilingual individual can easily use each of their two languages without much confusion or mishap? This question has been widely studied by psychologists that are keen to better understand multilanguage control. The present study seeks to shed light on the controversy between two opposing models of dual language control. The inhibitory control model (Green, 1998) predicts that activation of a word in one language inhibits activation of words in the other language. The level of activation model (Grosjean, 1997) proposes that activation of the language in use is increased over the other. In two experiments, monolingual and bilingual (English-French) participants decided if a string of letters presented in the middle of a computer monitor was an English word or not. At the same time, a distractor word was presented to either the left or right of the letter string, and it was English or French and related in meaning or not. French semantically related distractor words provoked interference to lexical processing in bilinguals whereas English semantically related distractor words provided a benefit to lexical processing in monolinguals. The different response patterns to semantically related distractors in the two groups suggest that the English-word decision was inhibited by activation of French words in bilingual participants. This result is consistent with the prediction of the inhibitory control model.

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Interhemispheric Communication: How do First and Second Languages Interact?

Despite the high prevalence of bilingualism, how individuals acquire, comprehend, and produce a second language (L2) is not well understood. In part, this is due to less extensive study of bilingualism than monolingualism (Grosjean, 1998) and, in part, from competing theoretical models. For example, some researchers have proposed a language-independent lexicon (i.e., one umbrella lexicon for many languages; e.g., see Grosjean, 1997 for a review), while others have proposed language-dependent lexica (i.e., separate language lexica for each language representation; Weinreich, 1953). Some propose language switching comes at a cost (e.g., Green, 1998; Macnamara, 1967), while others suggest no cost (e.g., Chan, Chau, & Hoosain, 1983; Grosjean, 1997). Some suggest that control of language selection and output involves inhibitory interaction between the languages (Inhibitory Control Model; Green, 1986, 1998), while others suggest control operates from relative level of excitation of each language (Level of Activation Model; Grosjean, 1997). The question of language control is the focus of the current research. The goal is to test the conflicting predictions of the Inhibitory Control (IC) model (Green, 1986, 1998) and the levels of activation model (Grosjean, 1997) of bilingual lexical control. Bilingual lexical control involves the *mental lexicon,* which is the mental "dictionary" of words associated with language. This dictionary reflects the *orthography* (i.e., the spelling of the words in a language), the *phonology* (i.e., the sound of the words in a language), and also the *semantics* (i.e., the meaning of words in a language) of familiar words (Altarriba & Heredia, 2008) a Bilingual has two collections of words, each associated with one particular language. These collections are differentiated by symbols where L1 refers to the native or dominant language and L2 refers to the second or less dominant language. A question in this thesis is how one of two languages is selected for use and comprehension. To better understand how this might occur, a review of monolingual lexicon is necessary.

**Monolinguals**

It has been suggested that the two hemispheres of the brain can process language independently (e.g., Iacoboni & Zaidel, 1996). Iacoboni & Zaidel used cued unilateral or bilateral lexical decision tasks to determine the independent word processing ability of the individual hemispheres. They found that unilateral trials produced faster and more accurate responses than bilateral trials suggesting that the individual processing of each hemisphere is better than the simultaneous processing of two hemispheres. Furthermore, their results revealed a response hand by visual field presentation interaction where left hand responses were faster and more accurate with LVF displays and right hand responses were faster and more accurate with RFV displays. These results suggest that each hemisphere can process words independently.

It has also been demonstrated that the hemispheres can interact because the corpus callosum, which connects the two hemispheres, allows for the passage of information between them (Sperry, 1982). Moreover, it has well been documented through experience and innate biology, that a hemisphere may become advantaged at a task (Wey, Cook, Landis, Regard & Graves, 1993). Indeed, the left hemisphere advantage (LHA) for language processing of words has been long documented (Iacoboni & Zaidel, 1996; Leiber, 1976; Rutherford, 2005).

To study a LHA for language processing, researchers use a lexical decision task (LDT) where letter strings (i.e., target letter string) are presented on a computer monitor and the participant must decide if the letter string is or is not a word. To load target processing to one or other hemisphere, one procedure uses a central target together with a distractor to either the left visual field (LVF) or right visual field (RVF). The distractor is presented very briefly (i.e., 150 ms) in order to temporarily disengage the contralateral hemisphere from the target letter string. The distractor then can be manipulated to be semantically related or not to the central target. Research using this type of LDT has demonstrated that when two words are simultaneously presented to each of the hemispheres, and those words are semantically related, then response time and accuracy of processing the central target are (decrease in RT shows better performance) negatively impacted (Underwood, Rusted, & Thwaites, 1983). The important implication of this research is that it demonstrates that both hemispheres can simultaneously process different stimuli and moreover, that the hemispheres interacting with one another ultimately influences processing.

More recent research has demonstrated that when each hemisphere is simultaneously presented word pairs, then the right hemisphere receives a benefit from left hemisphere processing (Weems & Zaidel, 2005). In this study, the authors used a lateralized LDT where two letter strings (i.e., either a word or nonword) were presented to the LVF and RVF on a horizontal plane. The authors investigated whether repetition priming would occur when a word presented to one hemisphere was later presented to the other. Repetition priming occurs when the presentation of one stimulus activates a neural network for that individual representation, which may facilitate the processing of subsequent stimuli, as long as these stimuli share at least one characteristic in common with the previous stimulus (i.e., semantics, orthography, or phonology). They found that RVF presentation of a word benefited both successive LVF and RVF presentations of the same word, but LVF presentation of a word only benefited a successive presentation in the LVF. The authors submit that interhemispheric communication is greater from the left to right hemisphere than right to left hemisphere. Thus, the right hemisphere benefits from what the left hemisphere processes. This effect does not appear to occur from the right to left hemisphere.

**Bilinguals**

Bilingual individuals have been suggested to form a heterogeneous group (Grosjean, 1998). Their lexical representations may vary depending on the age at which they learned the language (i.e., age of acquisition; Kim, Relkin, Lee, & Hirsch, 1997), the individual's level of competence in both comprehension and production of L2 (Javier, 2007), context of acquisition (i.e., learned two languages together from birth vs. learned one language at home and one at school; Javier, 2007), and number of languages (Kujalowicz & Zajdler, 2009). Age of acquisition (AoA) has been suggested to drive a different neural representation, in relation to lateralization of the languages, of those bilinguals who learned the both languages before the age of six than those who learned L2 after the age of 12 (Soares & Grosjean, 1984). These authors contend that there is a *critical period* for language acquisition, which ends around the same time as puberty (Paradis, 1994). Moreover, Genesse *et al.* (1978) suggest that learning a second language after the age of 12 leads to an increased involvement of the right hemisphere for L2 processing, which would decrease the previously mentioned LHA for language abilities.

According to Romaine (1995), there are three theories on lateralization in bilinguals that have received some support: LHA for both languages; weaker left lateralization for languages in bilinguals; and differential lateralization for the two languages. Evidence in support of greater right hemisphere involvement comes from a study conducted by Genesse *et al.* (1978). These authors investigated links between the AoA of a second language and the degree of hemispheric involvement. Three groups of bilinguals were compared: simultaneous acquisition, L2 acquisition between the ages of 4-6, and L2 acquisition after the age of L2. Participants were presented stimuli in both languages and had to identify to which language the stimuli corresponded, while measuring EEG response. They found that infant and childhood bilinguals had shorter wave peak latencies in the left hemisphere for both languages, while adolescent bilinguals showed shorter latencies in the right hemisphere for both languages. These results suggest that late bilinguals used a more right-hemisphere holistic approach for both languages.

Contrary to the aforementioned study, in a recent meta-analysis that supports differential lateralization for languages depending on AoA, Hull & Vaid (2007) examined bilingual functional lateralization based on studies that directly compared both monolinguals and bilinguals. These authors found that monolinguals and late bilinguals were reliably LH dominant across language tasks regardless of proficiency, whereas early bilinguals showed reliable bilateral hemispheric involvement. This finding is supported by an earlier meta-analysis where comparable differences between early and late bilinguals were also reported (Vaid & Hull, 1991). Taken together, this evidence suggests that the primary predictor of functional language lateralization in adulthood is whether an individual learned one versus two languages early in childhood.

Another area of debate is how more than one language network is represented within the brain. The most common view for lexical storage in bilinguals is a hierarchical model in which there are two layers of conceptual/memory representations or nodes (Cook, 2002). For this particular model, these layers consist of a lexical layer (i.e., represents form information of each language) and a semantic/conceptual layer (i.e., the meaning of the lexical item). Even though there are a variety of theoretical hierarchical models using this structure, they differ on the connections between the layers (see Cook, 2002 for a review). Kroll (1993) proposes a recent version of this model, which assumes both a direct link between a translation pair’s L1 and L2 form representations (i.e., lexical layer) and vice versa. Furthermore, it assumes an indirect connection between these representations through the conceptual node shared between L1 and L2 (a connection that includes a direct link between the L1/L2 conceptual node and the L1 and L2 form nodes). This forms a 3-way connection between the conceptual node and the two lexical representations. Even though this model assumes connections between all parts of layers, it also posits directional strength differences between nodes, where there is a strong link between L1 - conceptual layer and L2 to L1 form nodes and where there is a weak link between L2 - conceptual layer and L1 to L2 (See F*igure 1*). The organization of this model can be influenced by the aforementioned characteristics of bilingualism (e.g., AoA, relative fluency, context).

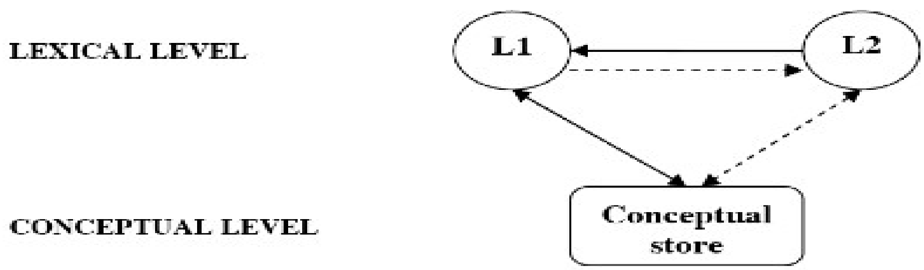


Figure 1. The asymmetrical model (from Kroll 1993: 69).

Included in the aforesaid model of lexical representations is the idea of separate versus integrated layers. Bilingual researchers investigate whether the memory units in each of the two levels are segregated by language or instead integrated across languages. Segregation implies that the stored semantic and lexical (i.e., orthographical and phonological) units are language-specific (i.e., there is a separate semantic and lexical representation for each of the two words in a translation pair; e.g., one for the word *boy* and one for the French translation *garçon* in the French/English bilingual). Integration implies that the semantic and lexical representations are shared - either partially or completely - between the two languages such that there is just one semantic/conceptual representation for the words *boy* and *garçon* and two branching lexical units, within one large lexicon. A third alternative is that integration holds for semantics and separation holds for orthography. Several studies have addressed this question and some (e.g., Schwanenflugel & Rey, 1986; Fox, 1996) have come to the conclusion that bilinguals possess a shared semantic representational system.

For evidence of an integrated semantic representation, Kolers (1966) conducted a study to demonstrate that words in two languages would facilitate recall. He posited that words from each language would comprise a single semantic system where each word would be tagged according to the language to which it belongs (i.e., an integrated semantic layer and two separate orthographical form nodes for each language). In support of his model, Kolers conducted a study where bilingual participants recalled words from a list that contained two languages. He found that recall was facilitated when words were presented more that once, regardless of if the repetition was in the same or different language. For example, presentation of the word *livre* (i.e., English for book) and the word *book* was equal to seeing book twice. Recall increased linearly with the frequency of occurrence of meaning rather than form, suggesting that the semantic representations are integrated across languages.

Further empirical support for an integrated semantic representation was provided by Guttentag, Haith, Goodman, & Hauch (1984). These authors conducted a variation on the LDT involving bilinguals to determine if simultaneous presentation of semantically related words would ultimately affect response times. For the study, they used participants who spoke both French and English. French target words were presented with flanker words, which were located above and below the target word and were either English or French words. This created a column of three words with the top and bottom flanker words being the same. Moreover, the flanker words were either related in meaning or not to the target word. The participants, who were all native French speakers with English as a second language, had to verbally report if the target word belonged to one of four semantic categories (i.e., metals, clothing, furniture, and trees). The participants responded to “oui” or “non” (i.e., “yes” or “no”) for group inclusion or not. For group inclusion, two semantic categories were grouped together to form one response option while the other two semantic categories were grouped to form the second response option (e.g., metals and trees were responded to by saying “yes” and clothing and furniture were responded to by saying “no”). Response times to verbal report were measured. Given that responses were slower when the flanker words were semantically related to the target word, their results indicated that participants could not ignore the flanker words even when they were printed in a different language. Moreover, this indicates that stimuli were processed simultaneously because presentation of flankers altered response times. In addition to lending support to an integrated semantic/conceptual representation, this study suggests that activation of a lexical representation (i.e., orthography and phonology) is *language-nonselective* in that activation of one language lexicon simultaneously activates the second. This is evidenced by the similar interference the participants demonstrated when flanker words were simultaneously flashed in either the same or other language. This study does not, however, test for hemispheric asymmetries by altering the display of distractor words to individual visual fields. Thus, they cannot conclude the impact of each hemisphere in bilingual language processing.

Research findings similar to the aforementioned studies have demonstrated that bilingual lexical access is initially language nonselective, where bilinguals reading words in one of their two languages activate orthography, phonology (i.e., language forms), and semantics in both languages (Dijkstra & van Heuven, 2002; Kroll, Sumutka, & Schwartz, 2005). Cook (2002) argues that in total nonselectivity, irrespective of contextual factors (e.g., topic of conversation, experimental setting), external input or internally-generated conceptual content (i.e., thinking) always activates lexical representations in both the bilingual's language forms – and always to the same extent. Ultimately, the correct language form is selected for both proper comprehension and, possibly, production. Now the question must be put forth: If separate language lecixa are simultaneously activated, how is it, then, that a bilingual can accurately access the appropriate lexicon for both perception and production? There are two opposing models of a L2 production/comprehension that will be focus of the present paper: the Inhibitory control (IC) model (Green, 1986, 1998) and the Levels of activation (LoA) models (Grosjean, 1997).

The IC model (Green, 1986, 1998) purports that language control is exerted through a process of active inhibition between the language entries at both the lexical and semantic levels. Upon perception or production of output, lexical representations are initially activated in both languages. In response to contextual information (e.g., current language in use, topic of conversation, laboratory settings), the targeted or selected language reactively inhibits activation of the other language through the use of language *tags*. This inhibitory effect acts in a feed-forward manner successive inhibition of opposing lexical representations (i.e., orthographical layer), and thus fluency in the target language, is more easily obtained. According to this model, inhibition is stronger from L1 to L2 so that switching the target language to L2 must overcome greater levels of inhibition whereas switching from L2 to L1 would be more easily obtained. This is supported by studies of the *slip-of-the-tongue* phenomenon where one is speaking fluently in L2 accidentally uses a word from L1 (Poulisse, 1999). This occurs because the relative inhibition from L2 to L1 for that particular concept is very weak or nonexistent and the wrong lexical representation is activated (i.e., the nontarget representation is produced or comprehended) because of the lack of inhibition. While the model does predict communication between L1 and

L2, it does not do so for L2 to L1 because of the strong inhibition of L2 from L1. Thus, this model predicts that input from L2 will not affect processing of L1 because of the strong level of active inhibition from L1.

The LoA models (Grosjean, 1997) suggest that language control can be exerted in response to the specifics of the contextual information (e.g., experimental factors, task demands, language currently in use) where correct language selection depends on the relative activation of form nodes (i.e., orthographical layers) of each language. That is to say, both form nodes are active (i.e., language-nonselectivity); however, based on the current contextual information, the target language form is more active. Furthermore, this model posits that as an individual is speaking fluently in one language, the relative threshold of activation is decreased so that successive activation is more easily obtained (i.e., ability to continue to speak fluently in one language). Moreover, the prediction that arises from LoA model is that the transfer of information between languages could occur because both lexical representations are activated.

The present research investigates whether the control mechanism in bilingual individuals operates through inhibition or relative levels of activation. Monolinguals (i.e., English speaking only) and English-French bilinguals will be presented English words or English-like pseudowords in a centralized LDT. Distractor letter strings will be either semantically related or not to the central target letter string and either French, English, or a pseudoword creating five distractor conditions. Based on the results of Underwood *et al.* (1983) study, the prediction that arises is: For both monolingual and bilingual groups, participants should show slowing to a target that is accompanied by a semantically related distractor that is English. This follows from the contention that simultaneous processing of semantically related words by each of the hemispheres leads to conflict between the hemispheres (Underwood et al., 1983).

In addition, the IC model (Green, 1986, 1998) predicts that both groups should perform similarly when a distractor is a French word or a pseudoword. This follows from the prediction that the English lexicon should be actively inhibiting the French lexicon in bilinguals, and from the fact that French distractors are much like pseudowords for monolinguals because they are unfamiliar.

In contrast, the LoA model (Grosjean, 1997) predicts that bilinguals will be slower and less accurate than monolinguals when a distractor is a semantically related French word. These predictions follow from the contention that the French lexicon is active, albeit less active than the English lexicon. Accordingly, the French words that are semantically related should trigger processing similar to the English words, which should provoke interference in the bilingual individualsThus, by systematically manipulating the distractor, we can test the predictions of the aforementioned models of bilingual language control.

## Experiment 1

This experiment investigated whether or not simultaneous presentation of a distractor that was either semantically related or not to the central target and French or English or a Pseudoword would affect lexical processing of monolinguals.

## Method

### Participants

A convenience sample of 28 English monolinguals (5 males, 23 females; $M_{age}$ = 20, age range = 18-26) participated in the present study. All had normal or corrected-to-normal vision, scored 6 or higher for right-handedness on the Annett Handedness questionnaire, scored above the 50$^{th}$ percentile on the Woodcock-Johnson-Word-Attack test of phonological processing, and reported no history of reading disability. Also, all were fluent only in English as, according to

Van Assche *et al.* (2009), fluency in a second language ultimately influences how an individual processes their native language.

Participants were recruited through the UBC Okanagan SONA online subject pool system. Participants were awarded either 0.5% bonus credit to an eligible psychology course or $10.00.

**Materials**

**Demographics questionnaire.** Gender, age, first language learned, and French language proficiency was recorded.

**Handedness questionnaire.** The Annett (1970) handedness questionnaire includes 12 action items. Participants indicate which hand is habitually used to perform each task (e.g., writing) and a score of -1, 0, or 1 is assigned to each "Left," "Either," or "Right" response, respectively. The numbers are added and the resulting sum ranges from minus 12 (strong left hand preference) to plus 12 (strong right hand preference). A score of 0 indicates ambidextrous. A score of 6 or greater was required for inclusion in the study.

Handedness was controlled because evidence (Springer & Deustch, 1998) suggests that handedness may be a confounding variable in tests of laterality of reading. The Annett handedness questionnaire was chosen for its usefulness in detecting any trace of sinistrality and its high internal validity (0.87; Williams, 1991).

**French Fluency.** Fluency in French was initially assessed by self-report. Participants who reported fluency or 10+ years of French education in the Canadian school system (English or French immersion) or any other form of learning French, which suggested fluency (i.e., long-term exchange program, lived in Quebec) were administered a French proficiency questionnaire (Rivère, 2009). This test, which was designed to determine proficiency at a third year university level, includes ten French sentences with a high difficulty rating. Individuals were required to translate the sentences from French to English. A score of 70% or more was deemed fluent (i.e., bilingual) and a score of 69% or less indicated nonfluent (i.e., monolingual). Participants who did not meet self-report criteria for possible fluency were not administered the French proficiency questionnaire.

**Woodcock-Johnson Word Attack.** This subtest of the Woodcock-Johnson-Revised Tests of Achievement assesses phonological ability. A series of 30 orthographically correct letter strings (i.e., fake words) that are not words are read aloud and pronunciation is scored. Participants were awarded one point for correct pronunciation and no point for incorrect pronunciation. The score is compared to age- or grade-related norms to provide a standardized measure of phonological ability. As the scoring is based on English-sounding pronunciations and the test was administered to bilingual as well as the monolingual participants, the rank for inclusion in the study was set at the $25^{th}$ percentile or higher for bilinguals and $50^{th}$ percentile or higher for monolinguals.

## Apparatus

Displays were programmed using Inquisit software, version 3.0, to appear on an IBM compatible Pentium 1 computer. All letter strings consisted of 4-6 letters and were presented in white System Times New Roman 14-point font against a black background and were either the target for lexical decision or a distractor, which appeared to the left or right at a 50% probability.

Target letter strings were presented at centre screen and were either words (e.g. *leaf)* or pseudowords (i.e., letter strings that meet the rules of English grammar but do not spell a word; e.g. *chout*). All target words were nouns and high (i.e., >6 on a 7pt. scale), medium (i.e., 3.51>x<5.9 on a 7pt. scale), or low (i.e., <3.5 on a 7pt. scale) in familiarity (Clark & Paivio, 2004)

Distractor letter strings were presented either to the left or right of the target and subtended 3 dg. of visual angle from the center of each letter string to the center of each distractor. The longest distractor letter string's medial edge subtended 2.1 dg. of visual angle from the center of the target word. Furthermore, the smallest distance between the nearest medial edge of the distractor and the distal edge of the central target letter string was 1.1 dg. of visual angle. Distractors were one of five types relative to the target (e.g., *leaf*): a semantically- related English word (ESR; e.g., *tree*), a nonsemantically related English word (ENSR; e.g., *boat*), a semantically- related French word (FSR; e.g., *tige*), a nonsemantically related French word (FNSR; e.g., *oeil*), or a pseudoword (PW; e.g., *afel*). Distractor words that were French were of medium (i.e., 2 >x< 2.5 on a 3pt. scale) or low (i.e., < 1.99 on a 3pt. scale) familiarity according to the online Lexique database (New & Pallier, 2001). Likewise, distractor words that were English were of medium (i.e., 3.51 >x< 5.9 on a 7pt. scale) or low (i.e., < 3.5 on a 7pt. scale) familiarity according to Clark and Paivio's (2004) word norms. Familiarity of distractor words was balanced across each of the high/medium/low familiarity target word conditions.

A Free Association Norms list (Nelson, McEvoy, & Schreiber, 1998) was used to determine semantic relatedness. Word pairs in the semantically related conditions (ESR and FSR) were chosen so that the highest semantic associate was used as long as the criteria for word length and familiarity were met. For the FSR condition, the semantically related English word was translated into the French equivalent, which then had to meet criteria for word length and familiarity. All word pairs were balanced across blocks and trials.

**Procedure**

Each participant was individually tested in a quiet laboratory room. After reviewing and signing the consent form, the participant completed the handedness questionnaire, the demographic questionnaire, French proficiency test (if bilingual), Word Attack test, and then the computer task. For the computer task, the overhead lights were shutoff and two lights that pointed toward the floor were illuminated to the left and right of the computer to ensure that level of illumination was consistent at each side of the monitor. The participant was seated with his/her head position stabilized by a chin rest situated 57 cm from the center of the computer monitor. To begin a trial of the lexical decision task, the participant depressed the space bar on the keypad. A fixation cross appeared for 500 ms and then was replaced by a centered target word, which appeared for only 50 ms. Simultaneously with onset of the target, a distractor appeared in either the LVF (i.e., right hemisphere distractor) or the RVF (i.e., left hemisphere distractor) for 50 ms, which was deemed short enough to tap into subconscious processing by the appropriate hemisphere, but not conscious processing. To respond positively that the central target was a word, the participant depressed the f and j keys with the left and right index fingers, respectively. To respond that the central target was not a word, the participant depressed the d and k keys with the left and right middle fingers, respectively. A trial was terminated by either a key press or after 2 s, which ever came first.

Three test blocks of 80 trials each followed a block of 16 practice trials. Each block of test trials randomly presented 40 target words and 40 target PWs. Each type of target was accompanied by one of the five types of distractors for a total of 8 trials per distractor type: 4 to the LVF and 4 to the RVF.

## Design

This was a 2 (string type: word or pseudoword) X 2 (distractor location: LVF or RVF) X 5 (distractor type: ESR, ENSR, FSR, FNSR, PW) repeated-measures design. Response time and accuracy were measured.

## Results

Separate analyses using a .05 alpha level were conducted on the average score of response time and accuracy in each of the 20 conditions for each participant.

### Response times

A three-factor within-subjects analysis of variance (i.e., a 2 X 2 X 5 repeated measures ANOVA) was performed to examine response times as a function of target string type (word or pseudoword), distractor location (RVF or LVF), and distractor string type (ENSR, ESR, FNSR, FSR, PW). As expected, the overall analysis revealed a main effect of target string type [$F$ (1, 27) = 61.510, $p < .001$, $\eta^2 = 69.5\%$] that was due to faster responses to words ($M$ = 748.431, $SE$= 23.760) than pseudowords ($M$ = 833.362, $SE$ = 32.159). A significant target X distractor type interaction was also found [$F$ (1, 27) = 2.872, $p < .05$, $\eta^2 = 32.4\%$] as well as a significant distractor location X distractor type interaction [$F$ (4, 24) = 5.640, $p < .05$, $\eta^2 = 48.5\%$]. No other main effects or interactions were found. Given the main effect for target string type and that pseudoword targets are not relevant to the hypotheses for the current research separate analyses of word targets were conducted.

When a 2 X 5 repeated measures ANOVA was conducted using only word target letter strings, neither a main effect of distractor location [$F$ (1, 27) = 3.614, $p = 0.068$, $\eta^2 = 11.8\%$] nor a main effect of distractor type [$F$ (4, 24) = 0.934, $p = 0.461$, $\eta^2 = 13.5\%$] were found. However, there was a significant distractor location X distractor type interaction [$F$ (4, 24) = 4.051, $p$ <

0.05, $\eta^2 = 40.3\%$]. To elucidate the source of the interaction, separate analyses of meaningful and nonsensical distractor types were conducted within each distractor location.

For the following analyses, the five types of distractors were separated into two conditions: meaningful distractors (ESR and ENSR) and nonsensical distractors (FSR, FNSR, and PW). This was done because monolinguals are only familiar with words that are English and they are neither familiar with pseudowords nor French words (i.e., both should be processed similarly).

In the first analysis to elucidate the source of the previous interaction, an average response time (ms) was created for each new condition - meaningful and nonsensical - for each hemisphere. A 2 (distractor location) X 2 (distractor type: meaningful and nonsensical) ANOVA was conducted. A significant main effect of distractor location [$F$ (1, 27) = 6.310, $p < 0.05$, $\eta^2 = 18.9\%$] was due to faster responses in the LH ($M$ = 740.027, $SE$ = 22.874) than the RH ($M$ = 757.456, $SE$ = 25.082). This supports the contention that the LH is advantaged over the RH for language abilities. However, the main effect was modified by a significant distractor location X distractor type interaction [$F$ (1, 27) = 9.533, $p < 0.05$, $\eta^2 = 26.1\%$]. Further analyses were conducted to investigate the source of the interaction.

An analysis of the distractor types within the LH did not reveal a significant effect [$F$ (1, 27) = 2.056, $p = 0.163$, $\eta^2 = 7.1\%$]. Moreover, an analysis of the distractor types within the RH did not reveal a significant effect [$F$ (1, 27) = 3.533, $p = 0.071$ $\eta^2 = 11.6\%$]. This analysis, however, is approaching significance, which would indicate that the RH depends on the LH for its own processing ability. Further analyses were conducted on distractor types, comparing between the hemispheres, which revealed a significant effect for the meaningful distractor type [$F$ (1, 27) = 16.210, $p < 0.001$, $\eta^2 = 37.5\%$] that was due to faster responses in the LH ($M$ =

731.789, *SE* = 22.277) than the RH (*M* = 768.802, *SE* = 27.006). Accordingly, this suggests that the left hemisphere is advantaged for language processing, especially when a meaningful distractor is presented simultaneously. No main effect was found between the hemispheres for the nonsensical distractor condition [$F$ (1, 27) = 0.050, $p$ = 0.824, $\eta^2$ = 0.2%], suggesting that nonsensical distractors provide neither interference nor benefit to processing between the hemispheres.

To further elucidate the source of the aforementioned 2 (distractor location) X 5 (distractor type) interaction, separate analyses were conducted for the meaningful and nonsensical distractor conditions. Thus, a 2 (distractor location) X 3 (distractor type: FNSR, FSR, and PW) ANOVA was conducted on the nonsensical distractor data and a 2 (distractor location) X 2 (distractor type: ENSR and ESR) ANOVA was conducted on the meaningful distractor data.

For nonsensical distractors, neither a main effect for distractor location [$F$ (1, 27) = 0.050, $p$ = 0.824, $\eta^2$ = 0.002%] nor a main effect of distractor type [$F$ (2, 26) = 0.649, $p$ = .531, $\eta^2$ = 4.8%] was found. Moreover, there was no significant distractor location X distractor type interaction [$F$ (2, 26) = 0.481, $p$ = 0.623, $\eta^2$ = 3.6%], suggesting that the other hemisphere processing a nonsensical distractor, regardless of type, affected neither hemisphere. For meaningful distractors, however, a main effect of distractor location [$F$ (1, 27) = 16.210, $p$ < 0.001, $\eta^2$ = 37.5%] was due to faster response times when the LH was processing word target letter strings (*M* = 731.789, *SE* = 22.277) than when the RH was processing word target letter stings (*M* = 768.802, *SE* = 27.006), suggesting a LHA for language processing when meaningful distractors are present. Neither a main effect of distractor type [$F$ (1, 27) = 2.737, $p$ = 0.110, $\eta^2$ = 9.2%] nor a distractor location X distractor type interaction [$F$ (1, 27) = 3.567, $p$ = 0.070, $\eta^2$ =

11.7%] was found. However, upon analysis of F*igure 2* and considering the distractor location X distractor type interaction is approaching significance, further analyses were conducted within each hemisphere.

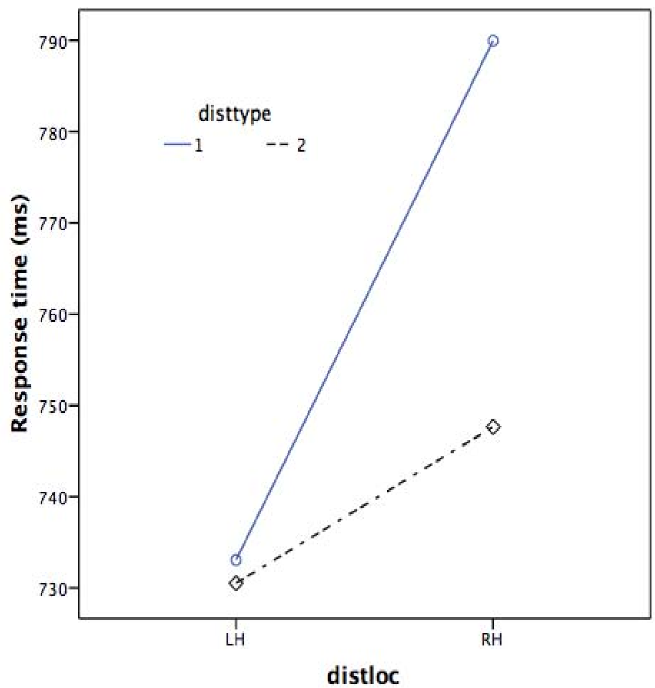


*Figure 2.* Mean response time scores to the central targets of monolinguals for each ENSR (i.e., 1) and ESR (i.e., 2) distractors when a LVF (i.e., LH) and RVF (i.e., RH) distractor is presented.

When the RH was processing the word target letter string, a significant main effect of distractor type [*F* (1, 27) = 4.700, $p < 0.05$, $\eta^2 = 14.8\%$] was due to faster responses when the LH was processing an ESR distractor (*M* = 747.645, *SE* = 26.072) than when the LH was processing an ENSR distractor (*M* = 789.958, *SE* = 31.134), suggesting that the there is a cost to RH processing when the LH is simultaneously processing a distractor that is ENSR. Moreover, when the LH was processing the word target letter strings, no significant main effect of distractor type [*F* (1, 27) = 0.031, $p = 0.862$, $\eta^2 = 0.1\%$] was found, suggesting that RH processing an meaningful (i.e., English) distractor does not affect the LH.

**Accuracy**

A three-factor within-subjects analysis of variance (i.e., a 2 X 2 X 5 repeated measures ANOVA) was performed to examine accuracy as a function of target string type (word or pseudoword), distractor location (RVF or LVF), and distractor string type (ENSR, ESR, FNSR, FSR, PW). The results revealed a main effect of distractor location [$F$ (1, 27) = 8.198, $p < 0.01$, $\eta^2 = 23.3\%$] that was due to better accuracy in the RH ($M$ = 0.852, $SE$ = 0.011) than the LH ($M$ = 0.823, $SE$ = 0.010). Moreover, a main effect of distractor type [$F$ (1, 27) = 9.756, $p < 0.001$, $\eta^2$ = 61.9%] was found. An analysis of the pairwise comparisons identified a significant difference between: ENSR ($M$ = 0.843, $SE$ = 0.013) and FSR ($M$ = 0.817, $SE$ = 0.010) where ENSR was more accurate ($p < 0.05$), FNSR ($M$ = 0.853, $SE$ = 0.012) and FSR ($M$ = 0.817, $SE$ = 0.010) where FNSR was more accurate ($p < 0.01$), PW ($M$ = 0.823, $SE$ = 0.013) and ENSR ($M$ = 0.843, $SE$ = 0.013) where ENSR was more accurate ($p < 0.05$), PW ($M$ = 0.823, $SE$ = 0.013) and ESR ($M$ = 0.843, $SE$ = 0.010) where ESR was more accurate ($p < 0.05$), and PW ($M$ = 0.823, $SE$ = 0.013) and FNSR ($M$ = 0.853, $SE$ = 0.013) where FNSR was more accurate ($p < 0.05$). The data also revealed a significant target letter string X distractor type interaction [$F$ (1, 27) = 36.430, $p < 0.01$, $\eta^2 = 57.4\%$] and a significant distractor location X distractor type interaction [$F$ (4, 24) = 8.198, $p < 0.01$, $\eta^2 = 68.6\%$]. No main effect of target letter string [$F$ (1, 25) = 2.030, $p = 0.167$, $\eta^2 = 7.5\%$] nor any other main effects or interactions were found, except a significant target letter string X distractor location X distractor type interaction [$F$ (4, 24) = 12.800, $p < 0.001$, $\eta^2$ = 68.1%] was found. In order to elucidate the source of the interactions and because pseudoword targets are not relevant to the hypotheses of the current research, separate analyses of only word targets were conducted.

A 2 (distractor location) X 5 (distractor type) ANOVA was conducted on word target letter strings. Neither a main effect of distractor location [$F$ (1, 27) = 2.377, $p$ = 0.135, $\eta^2$ = 8.1%] nor a main effect of distractor type [$F$ (4, 24) = 2.013, $p$ = 0.125, $\eta^2$ = 25.1%] was found. However, there was a significant distractor location X distractor type interaction [$F$ (4, 24) = 4.125, $p < 0.05$, $\eta^2$ = 40.7%]. To elucidate the source of the interaction, separate analyses of meaningful and nonsensical distractor types were conducted within each distractor location.

Consistent with the response time analyses, the five types of distractors were separated into two conditions: meaningful distractors (ESR and ENSR) and nonsensical distractors (FSR, FNSR, and PW). Again, this was done because monolinguals are only familiar with words that are English. For the first analysis to elucidate the source of the previous interaction, an average accuracy score was created for each new condition - meaningful and nonsensical - for each hemisphere. A 2 (distractor location) X 2 (distractor type: meaningful and nonsensical) ANOVA was conducted. The results revealed a significant main effect of distractor type [$F$ (1, 27) = 5.607, $p < 0.05$, $\eta^2$ = 17.2%] that was due to more accurate responses when a meaningful distractor was simultaneously presented ($M$ = 0.865, $SE$ = 0.013) than a nonsensical distractor ($M$ = 0.844, $SE$ = 0.012) No significant main effect for distractor location [$F$ (1, 27) = 1.153, $p$ = 0.293, $\eta^2$ = 4.1%] was found. However, the main effect of distractor type was modified by a significant distractor location X distractor type interaction [$F$ (1, 27) = 7.365, $p < 0.05$, $\eta^2$ = 21.4%]. Further analyses were conducted to investigate the source of the interaction.

An analysis of the distractor types within the LH did not reveal a significant effect [$F$ (1, 27) = 0.029, $p$ = 0.867, $\eta^2$ = 0.1%], suggesting that the LH is not affected by the simultaneous distraction of the RH. In contrast, an analysis of the distractor types within the RH did reveal a significant effect [$F$ (1, 27) = 10.140, $p < 0.01$, $\eta^2$ = 27.3%] that was due to more accurate responses when the LH was processing a meaningful distractor (*M* = 0.875, *SE* = 0.072) than nonsensical distractors (*M* = 0.814, *SE* = 0.081). This suggests that the RH is affected by the simultaneous LH processing of a distractor.

Further analyses were conducted on distractor types, comparing between the hemispheres. There was not a significant main effect of distractor location for the meaningful distractor type [$F$ (1, 27) = 1.583, $p = 0.219$, $\eta^2 = 5.5\%$]. However, there was a main effect of distractor location for the nonsensical distractor condition [$F$ (1, 27) = 6.245, $p < 0.05$, $\eta^2 = 18.8\%$] that was due to more accurate responses by the LH (*M* = 0.858, *SE*= 0.082) than the RH (*M* = 0.814, *SE* = 0.081). This suggests that there is a cost to accuracy when the LH is processing a nonsensical distractor and that the RH is affected by LH processing.

To further elucidate the source of the aforementioned 2 (distractor location) X 5 (distractor type) interaction, separate analyses were conducted for the meaningful and nonsensical distractor conditions. Thus, a 2 (distractor location) X 2 (distractor type: ENSR and ESR) ANOVA was conducted on the meaningful distractor data and a 2 (distractor location) X 3 (distractor type: FNSR, FSR, and PW) ANOVA was conducted on the nonsensical distractor data.

For nonsensical distractors, a significant main effect of distractor location [$F$ (1, 27) = 6.245, $p < 0.05$, $\eta^2 = 18.8\%$] was due to more accurate responses by the LH (*M* = 0.858, *SE* = 0.015) than by the RH (*M* = 0.813, *SE* = 0.015). This suggests that the LH is advantaged when processing language, even when the RH is processing a nonsensical distractor. No main effect of distractor type [$F$ (2, 26) = 0.581, $p = 0.566$, $\eta^2 = 4.3\%$] was found. However, a significant distractor location X distractor type interaction [$F$ (2, 26) = 3.912, $p < 0.05$, $\eta^2 = 23.1\%$]

modifies the previous main effect. Further analyses were conducted to examine the source of the interaction.

When the LH was processing the central target word, no main effect of nonsensical distractor type [$F$ (2, 26) = 0.626, $p$ = 0.543, $\eta^2$ = 4.6%] was found, suggesting that the accuracy of the LH is not affected by RH processing of a nonsensical distractor. Moreover, when the RH processed the central target word, there was no significant main effect of nonsensical distractor type [$F$ (4, 26) = 3.325, $p$ = 0.052, $\eta^2$ = 20.4%]. Given the source of the interaction was not revealed in the previous analyses, an examination of F*igure 3* provoked an analysis of FSR distractor type between the hemispheres.

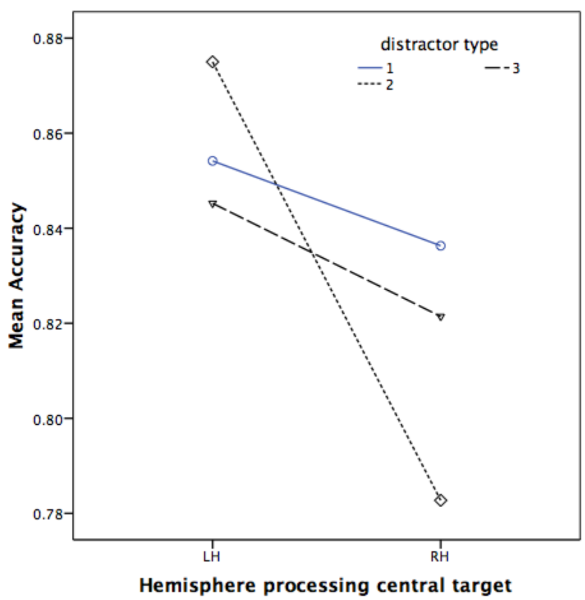


*Figure 3.* Mean accuracy scores of monolinguals for nonsensical distractors: FNSR (i.e., 1), FSR (i.e., 2), and PW (i.e., 3) in the LH and RH.

This analysis revealed a significant main effect of distractor location [$F$ (1, 27) = 13.49, $p$ < 0.001, $\eta^2$ = 33.3%] that due to more accurate responses in the LH ($M$ = 0.875, $SD$ = 0.095) than the RH ($M$ = 0.783, $SD$ = 0.102). This suggests that there is a cost to RH accuracy when the

LH is processing a FSR distractor. This finding is puzzling because a nonsensical distractor should not exert any influence on processing, as revealed by the previous analyses. No other main effects were found for the nonsensical distractor types when comparing between the hemispheres.

For meaningful distractors, neither a main effect nor interaction was found, suggesting that the accuracy for either hemisphere remains unaffected by the simultaneous processing of any meaningful distractor. An inspection of F*igure 4* suggests a trend where the RH receives a benefit from LH processing of a distractor that is ESR. This, however, was not statistically supported.

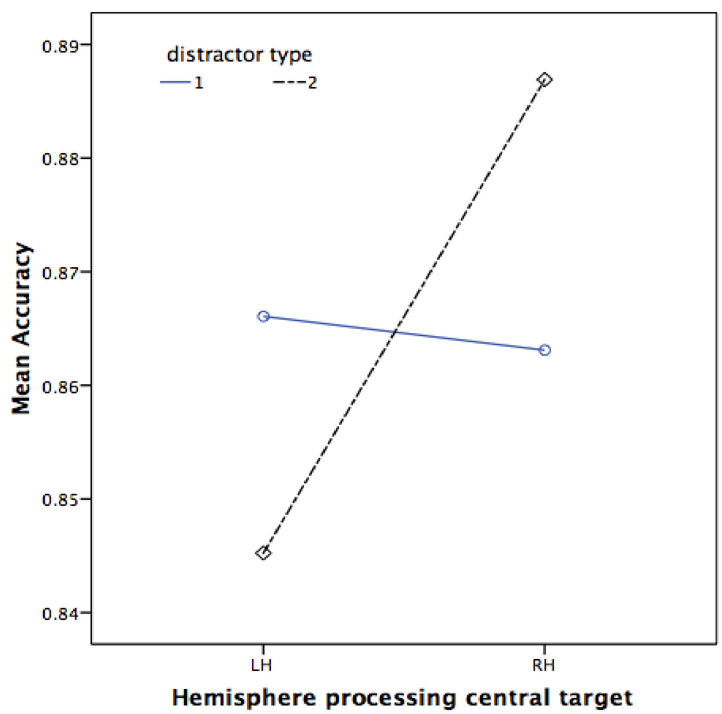


*Figure 4.* Mean scores representing accuracy for ENSR (i.e., 1) and ESR (i.e., 2) for each distractor location: LVF (i.e., LH) and RVF (i.e., RH).

## Discussion

As is consistent with previous research, word target letter strings were responded to faster than pseudoword letter strings (Underwood et al., 1983) and, moreover, evidence was found for a

LHA of language processing (Chiarello, 1985; Iacoboni & Zaidel, 1996; Leiber 1976; Rutherford, 2005). An overall main effect of distractor location was approaching significance and further analyses (i.e., the averaged analysis of meaningful and nonsensical distractors) revealed faster response times for the LH (i.e., LHA). An explanation for the nonsignificance in the overall analysis for distractor location is a lack of power. Our study contains a large number of conditions, which ultimately affects statistical power. Moreover, this explains why a significant main effect of distractor location was found in subsequent analyses that involved fewer conditions.

Additionally, the results for the monolingual group were consistent with our predictions that the pseudoword and French distractor types (i.e., nonsensical distractors) would not benefit the processing of either hemisphere. Nonsensical distractors did, however, provoke a cost to accurate RH processing. This, in part, can be explained by the contention that the RH depends on LH processing for its own processing ability (Weems & Zaidel, 2005) in that LH processing of a nonsensical distractor costs RH processing of a target word.

Our study was modeled after a similar study by Underwood, Rusted, & Thwaites (1983), with the addition of a second language, to test the lexical processing of both monolingual and bilingual participants. Following the outcome of their study, we predicted that, for the monolingual group, there would be a slowing of response times to English distractors that were semantically related to the target letter string. However, our results did not support this prediction. In fact, our results are more consistent with recent research conducted by Weems & Zaidel (2005), who found that the RH benefits from prior presentation of a word to the LH, but LH does not benefit from the prior presentation to the RH. Our analyses revealed that RH processing of a word target benefits from the simultaneous RVF display (i.e., LH processing) of an English semantically related distractor compared to an English word that is not semantically related. In contrast, the LH did not benefit from the RH processing a semantically related word compared to one that was not semantically related. Indeed, RH processing of any type of distractor did not affect simultaneous processing of the LH (i.e., English semantically related or not, and nonsensical letter strings).

Our results for the monolinguals demonstrate that simultaneous hemispheric lexical processing of words ultimately affects the processing of the RH. There is a benefit to the speed of RH processing when the LH processes a semantically related word, compared to one that is not semantically related. Furthermore, the RH shows an increase in accuracy when the LH processes a distractor that is English compared to distractors that are nonsensical. That is to say, the RH relies heavily on the lexical processing of the LH.

## Experiment 2

This experiment tested predictions of the IC and LoA models of language control in English-French bilinguals by simultaneously presenting a distractor that was either semantically related or not to a central target and French or English or a Pseudoword.

## Method

### Participants

A convenience sample of 20 English-French bilinguals (9 males, 11 females; $M_{age}$ = 24, age range = 18-38, early-learner = 16, later-learner = 4) participated in the present study. All had normal or corrected-to-normal vision, scored 6 or higher for right-handedness on the Annett Handedness questionnaire, scored above 25$^{th}$ percentile on the Woodcock-Johnson-Word-Attack test of phonological processing, and reported no history of reading disability.

Participants were recruited through advertisements at the French Cultural Centre and the UBC Okanagan SONA online subject pool system. Participants were awarded either 0.5% bonus credit to an eligible psychology course or $10.00.

The materials, procedure, and design were the same as Experiment 1.

## Results

Separate analyses using a .05 alpha level were conducted on the average score of response time and accuracy in each of the 20 conditions for each participant in the bilingual group. The data for the bilingual group were not split into meaningful and nonsensical conditions, as in Experiment 1, because the majority of the distractor types were meaningful.

### Response times

A three-factor within-subjects analysis of variance (i.e., a 2 X 2 X 5 repeated measures ANOVA) was performed to examine response times as a function of target string type (word or pseudoword), distractor location (RVF or LVF), and distractor string type (ENSR, ESR, FNSR, FSR, PW). As in Experiment 1, the overall analysis revealed a main effect of target string type [$F$ (1, 19) = 25.110, $p < 0.001$, $\eta^2 = 56.9\%$] that was due to faster responses to words ($M$ = 742.673, $SE$ = 17.697) than pseudowords ($M$ = 822.604, $SE$ = 28.690). Moreover, a significant main effect of distractor location [$F$ (1, 19) = 25.110, $p < 0.05$, $\eta^2 = 28.2\%$] was found, which was due to faster responses by the RH ($M$ = 773.686, $SE$ = 21.814) than by the LH ($M$ = 791.591, $SE$ = 23.552). This suggests that, contrary to monolinguals, bilinguals may have a right hemisphere advantage (RHA) for language processing. This is supported by previous research on early-learner bilinguals who have increased RH involvement for language processing. No other main effects or interactions were found. However, given the main effect for target string type and that pseudoword targets are not relevant to the hypotheses for the present research, separate analyses of word targets were conducted.

When a 2 X 5 repeated measure ANOVA was conducted using only word target letter strings, no main effects or interactions were found. However, the main effect of distractor type approached significance [$F$ (1, 19) = 25.110, $p$ = 0.072, $\eta^2$ = 39.8%], suggesting that one or more of the distractor types may be causing interference for language processing. Unexpectedly, an analysis of the pairwise comparisons revealed a significant difference between FSR and ENSR distractor types ($p < 0.05$) that was due to slower responses when a FSR distractor ($M$ = 768.396, $SE$ = 22.248) was present than an ENSR distractor ($M$ = 723.921, $SE$ = 17.691). This suggests that the RH is affected by the simultaneous processing of the LH; in particular, that there is a cost to processing by the RH when the LH is distracted by a semantically related French word.

**Accuracy**

A three-factor within-subjects analysis of variance (i.e., a 2 X 2 X 5 repeated measures ANOVA) was performed to examine accuracy as a function of target string type (word or pseudoword), distractor location (RVF or LVF), and distractor string type (ENSR, ESR, FNSR, FSR, PW). Congruent with RT data, there was a significant main effect of target string type [$F$ (1, 19) = 4.670, $p < 0.05$, $\eta^2$ = 19.7%] that was due to more accurate responses to words ($M$ = 0.876, $SE$ = 0.012) than pseudowords ($M$ = 0.831, $SE$ = 0.018). There also was a significant main effect of distractor location [$F$ (1, 19) = 37.600, $p < 0.001$, $\eta^2$ = 66.4%] that was due to more accurate responses by the RH ($M$ = 0.881, $SE$ = 0.011) than by the LH ($M$ = 0.827, $SE$ = 0.013). Moreover, the results indicated a significant main effect of distractor type [$F$ (4, 16) = 12.670, $p < 0.001$, $\eta^2$ = 76.0%]. An analysis of the pairwise comparisons identified a significant difference between: ENSR ($M$ = 0.879, $SE$ = 0.018) and ESR ($M$ = 0.832, $SE$ = 0.013) where ENSR were more accurate ($p < 0.05$); ENSR ($M = 0.879$, $SE = 0.018$) and FSR ($M = 0.819$, $SE = 0.012$) where ENSR were more accurate ($p < 0.05$); ESR ($M = 0.832$, $SE = 0.013$) and PW ($M = 0.870$, $SE = 0.012$) where PW were more accurate ($p < 0.01$); FSR ($M = 0.819$, $SE = 0.012$) and FNSR ($M = 0.869$, $SE = 0.014$) where FNSR were more accurate ($p < 0.05$); and FSR ($M = 0.819$, $SE = 0.012$) and PW ($M = 0.870$, $SE = 0.012$) where PW were more accurate ($p < 0.01$). These pairwise comparisons suggest that both English and French distractors provoke interference (i.e., decreases in accuracy), especially when semantically related.

Further analyses of the 2 X 2 X 5 repeated measures ANOVA revealed a significant target letter string X distractor location interactions [$F$ (1, 19) = 44.120, $p < 0.001$, $\eta^2 = 69.9\%$] as well as a significant distractor location X distractor type interaction [$F$ (1, 19) = 4.210, $p < 0.05$, $\eta^2 = 51.3\%$]. Furthermore, a significant target string type X distractor location X distractor type interaction [$F$ (4, 16) = 4.956, $p < 0.01$, $\eta^2 = 55.3\%$] was found. In order to elucidate the source of the interactions and because pseudoword targets are not relevant to the hypotheses of the present research, separate analyses of only word targets were conducted.

When a 2 (distractor location) X 5 (distractor type) ANOVA was conducted with only words as the target letter string, only a significant main effect of distractor type [$F$ (4, 16) = 4.703, $p < 0.05$, $\eta^2 = 54.0\%$] was found. Further investigation of the pairwise comparisons for distractor type revealed the following significant differences: ENSR ($M = 0.892$, $SE = 0.019$) and FSR ($M = 0.825$, $SE = 0.013$) where ENSR distractors were more accurate ($p < 0.05$); FNSR ($M = 0.888$, $SE = 0.018$) and FSR ($M = 0.825$, $SE = 0.013$) where FNSR distractors are more accurate ($p < 0.05$); and FSR ($M = 0.825$, $SE = 0.013$) and PW ($M = 0.906$, $SE = 0.013$) where PW distractors are more accurate ($p < 0.05$). These pairwise comparisons are congruent with previous data in that they suggest an interference effect for French distractors, especially when semantically related to the central target. No other main effect or interaction was found.

Upon examination of F*igure 5*, an analysis of distractor types in RVF (i.e., RH processing of the central target) was conducted.

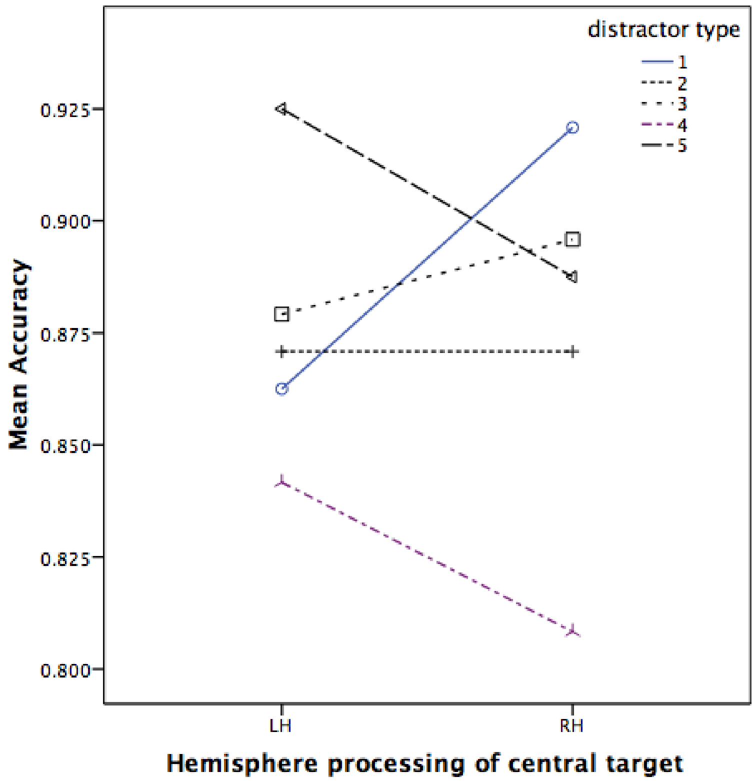


*Figure 5*. Mean accuracy scores of bilinguals for each distractor type: ENSR (i.e., 1), ESR (i.e., 2), FNSR (i.e., 3), FSR (i.e., 4), and PW (i.e., 5) in the LVF (i.e., LH processing) and the RVF (i.e., RH processing).

This analysis revealed a significant main effect of distractor type [$F$ (1, 19) = 17.080, $p <$ 0.001, $\eta^2$ = 47.3%]. Further analyses of the pairwise comparisons revealed a significant difference between ENSR ($M$ = 0.921, $SE$ = 0.019) and FSR ($M$ = 0.808, $SE$ = 0.021) that was due to more accurate responses in the presence of an ENSR distractor than a FSR distractor ($p <$ 0.01). These pairwise comparisons suggest that LH processing affects the RH, and furthermore, there is a cost to RH processing when a FSR distractor is simultaneously distracting the LH.

## Discussion

Consistent with the monolingual findings in Experiment 1 and with previous research (van Heuven, Schriefers, Dijkstra, Hagoort, 2008), bilinguals processed word targets faster and more accurately than pseudoword targets. However, inconsistent with the monolingual findings, the analyses of bilinguals revealed a RHA advantage for lexical processing (i.e., faster and more accurate responses to central targets by the RH). This can, in part, be explained by the increased RH involvement in lexical processing of early-learner bilinguals (Vaid & Hull, 2007) since they were the majority of the participants. This effect, however, does diminish in subsequent analyses of word targets, which further supports the contention that both the LH and RH are capable of processing meaningful lexical information (i.e., English word targets as compared to pseudoword targets). Also consistent with Experiment 1, the processing of the RH depends on the processing of the LH. This was evidenced by a significant slowing of RT and decrease in accuracy for RH processing of the central target when a FSR distractor was simultaneously presented to the LH. The interference effect also supports the IC model (Green, 1986, 1998), which predicts that switching between languages results in a cost of time. Inconsistent with the results from Experiment 1, the bilingual's RH did not receive a benefit to the simultaneous presentation of an ESR distractor. Even though the analyses with word targets did not reveal any significant main effects or interactions for the RT data, a significant effect of distractor type did emerge, which demonstrated that processing a distractor that is FSR causes interference to the speed and accuracy of lexical processing. This interference effect is also consistent with the IC model (Green, 1986, 1998) of bilingual lexical control because of the cost to RT when processing a French semantically related distractor.

## General Discussion

Our main results from Experiment 1 and Experiment 2 demonstrated that there are similarities and differences in how monolingual and bilingual participants process lexical information.

In both monolingual and bilingual participants, there is evidence that the RH is affected by LH processing, but not vice-versa, which converges with findings of a RH but not a LH benefit from repetition priming in the contralateral visual field (Weems & Zaidel, 2005). However, unlike the findings for monolinguals, the bilingual participants did not show a RH benefit from LH processing of a distractor that was ESR, and did show a cost to RH processing from LH processing of a FSR distractor.

The prediction of the LoA model (Grosjeam, 1997) for bilingual lexical control is that bilinguals should process semantically related French distractors similarly to English semantically related distractors because both language networks are active during processing. Thus, a bilingual's RH should receive a benefit from the LH simultaneously processing an ESR distractor and one that FSR. However, this prediction was not supported. Instead, there was no gain from LH processing of ESR distractor and a cost from LH processing of a FSR distractor. The interference effect, however, does lend support to the IC model (Green, 1986, 1998). This model predicts a cost associated with the suppressed language network overcoming inhibition from the language in use (i.e., English). Indeed, as predicted, there was slowing and a decrease in accuracy to RH processing when the LH was distracted by a FSR word.

Further plans for the present study will include increasing sample sizes for both the monolingual and bilingual groups. Also, for the bilingual group, it would be interesting to investigate if corroborating evidence would be found in L2 late-learners (i.e., learned L2 after the age of 12) since the majority of the bilingual group consisted of early-learners (i.e., learned L2 before the age of six). This arises from the argument that learning L2 after the age of 12 involves differential processing of the hemispheres (i.e., more left lateralized) than individuals who learned the language before the age of 6 (i.e., more right hemisphere involvement). Since evidence has demonstrated that monolinguals and late-learner bilinguals process lexical information in a similar manner (i.e., LHA for language processing; Hull & Vaid, 2007), it would be predicted that the RH of both groups would depend greatly on LH processing. Following this logic, monolingual and late-learner bilingual groups should perform similarly in that the RH would not receive any benefit from the LH processing of the French distractors (i.e., there would be a cost to RH processing when the LH is simultaneously processing a French distractor).

Considering evidence for the IC model of bilingual lexical control was found, it would be interesting to investigate whether or not input of semantically related words from L2 would benefit either of the hemispheres. To do this, a LDT would be used where bilingual and monolingual participants would decide if a target letter string is or is not a word, as was tested in the present study. However, central target words would be English, French, or Pseudowords where monolinguals would respond no to pseudowords and French words and bilinguals would respond no only to pseudowords (as they would be fluent in both French and English). Also similar to the present study, distractor letter strings (ESR, ENSR, FSR, FNSR, PW) would be presented to either the LVF or RVF. The critical manipulation for this study would involve successive presentation of same language words to one hemisphere (e.g., a LVF French distractor followed by a central French target that are both processed by the RH or vice versa). By presenting a French distractor to the RH followed by a French central target, it can predicted that the RH would have started, if not completed, the transfer of inhibition from English to

French. In this case, the RH would be primed for the French central target. Successive same-language trials would be compared to successive opposing-language trials to test the prediction that the RH of bilinguals would not receive any benefit to the processing of French words in opposing-language trials, but would receive a benefit to successive same-language ones.

The present study does have some limitations, but also offers novel strengths to the study of bilingualism. Both the monolingual and bilingual sample sizes were small, which may have led to some results not reaching significance (i.e., ultimately affecting the power of the statistical procedures). This is especially important because of the high number of conditions in the present study. The number of conditions, however, is a crucial strength of the present research because of the ability to make important comparisons between distractor types and between the hemispheres. Another strength lies in the comparison between the monolingual and bilingual participants by subjecting both groups to the same stimuli. This provides direct evidence that learning a second language does ultimately involve differential lexical processing.

Another limitation involves ecological validity; the rapid presentation of stimuli does not truly reflect a real reading scenario. This methodology, however, does test the contribution of automatic processing to reading. Furthermore, the present study does provide an increase in ecological validity over previous studies on bilingualism because of the central presentation of target letter strings (i.e., central presentation reflects a real reading scenario) as compared to lateral presentation of words in a LDT.

Apart from the importance in the pursuit of knowledge and understanding of the human bilingual brain, this study has other important implications. The present study is meant to offer a better sense of language and the brain. Why? Because understanding the complexities of the brain and language will help us better appreciate the myriad of multilingual skills we, as humans, are developing. In turn, this helps us more accurately recognize when problems are part of the natural milestones of language acquisition and when they are related to true learning problems or conflicts between languages. Furthermore, understanding how the brain handles multiple languages gives us further reason to celebrate the amazing feat of multilingualism. Indeed, the study of language itself is important because of the overwhelming significance of language in our everyday lives. As the world becomes increasingly more globalized and cultures and languages continue to mix, the frequency of bilingualism will increase accordingly. Thus, a complete understanding of the underlying mechanisms of the bilingual brain will aid acquisition of a second language form both a teaching and learning perspective.

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