RESOLVING BETWEEN-LANGUAGE AND WITHIN-LANGUAGE COMPETITION IN BILINGUALS

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Abstract

Friesen et al. (2011) reported behavioural and electrophysiological differences in how monolinguals and bilinguals resolved lexical competition in a picture selection task (PST). Participants selected a named picture from two alternatives that were related semantically, phonologically, or unrelated. Both groups were slower on related pairs, but the additional RT cost on semantically-related pairs was smaller for bilinguals than for monolinguals. Importantly, monolinguals exhibited attenuated N400s for semantically-related pairs while bilinguals did not. The current study pursued these results with a homogeneous group of English-French bilinguals performing the task in both languages. Measures of executive control, language proficiency, and language production abilities were acquired to investigate their influence in resolving interlingual and intralingual competition. In both languages, semantic pairs generated longer RTs than phonological and unrelated pairs and as in the earlier study, there was no modulation of the N400. There was no evidence for a relation between the PST and the flanker task. However, a relation was found between vocabulary knowledge and the PST in the weaker language.

Keywords: Lexical selection, bilingualism, ERP

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Resolving Between-Language and Within-Language Competition in Bilinguals

For every communicative interaction, bilinguals are required to manage and switch attention between two languages in accordance with the interlocutor's linguistic background and with the arising social context. Since the bilingual's two lexicons are integrated and language access is non-selective (see Kroll, Bobb, & Wodniecka, 2006, for a review), successful communication entails accessing only the intended lexical representations during comprehension and articulation. However, such a task becomes challenging when in addition to competition from the other language, there are also competitors that exist within a single language. Prior research has shown that during single-word recognition, lexical candidates that share acoustic properties (*book* and *boot*) and semantic properties (*cat* and *dog*) with an incoming word are activated in parallel (e.g., Marslen-Wilson, Moss, & van Halen, 1996; Norris, 1994), thus implying that hundreds of lexical candidates could be activated at once. Moreover, since bilinguals are fluent in two languages, lexical representations from the non-target language overlapping orthographically and phonologically with the incoming word are activated as well (e.g., Dijkstra, Grainger, & van Heuven, 1999; Jared & Kroll, 2001; van Heuven, Dijkstra, & Grainger, 1998). As a result, bilinguals are faced with a larger pool of lexical entries that compete for attention than is the case for monolinguals. This additive interference from cross-language competitors presents a unique selection problem that is non-existent for monolinguals, signifying possible differences between groups in how lexical competition is resolved. Currently, it is unknown what mechanism underlies lexical resolution in bilinguals and whether the same mechanism is engaged for both between- and within-language competition. The present study uses event-related potentials because of their high temporal acuity, in combination with behavioural measures, to examine the neural underpinnings associated with such resolution processes.

Event-related potentials (ERPs) measure electrical brain activity at the surface of the scalp and are time-locked to a specific event, such as the presentation of a word or picture. The resulting ERP waveform represents an average of the activity from similar trials, which consists of negative-going and positive-going peaks. Each peak is labeled according to its position within the waveform post-stimulus onset (e.g., P300 is a positive-going peak at 300 ms). The amplitude and latency of each ERP component provides information regarding the strength and timing of various cognitive processes (Coles & Rugg, 1995). This technique is valuable in the study of language, as it has been used extensively in identifying the neural basis for certain linguistic processes.

Between-Language Competition

Past research has demonstrated that bilinguals jointly activate the lexicons of both languages during visual word recognition (see Djikstra, 2005 for a review), speech production (see Kroll, Bobb, & Wodniecka, 2006, for a review), and auditory comprehension (Spivey & Marian, 1999; Marian & Spivey, 2003). For instance, using the picture-word interference paradigm, several researchers found that auditory distractor words that were phonologically related to the target picture’s translation produced longer naming latencies than distractor words that were unrelated to the picture (phonological-translation effect; Costa, Colomé, Gómez, & Sebatián-Gallés, 2003; Hermans, Bongaerts, de Bot, & Schreuder, 1998). In contrast, facilitation in naming occurred when the distractor word was the translation equivalent of the target picture. This effect has been termed the cross-language identity effect and has been reported for speakers of various language pairs naming pictures in their dominant and non-dominant language (e.g., Costa, Miozzo, & Caramazza, 1999; Hermans, 2004). Together, these findings support the claim that during language production, the bilinguals' non-target language is activated and competing for selection.

Further support for the simultaneous activation of two language systems comes from electrophysiological data. One ERP component that is well documented in the study of language processing is the N400. The N400 is a negative-going peak 400 ms post-stimulus onset that is maximal over central-parietal electrodes (however, the N400 effect appears to be more frontally-distributed for pictures and auditory words; refer to Kutas & Federmeier, 2011, for a review). The N400 has been described as reflecting the process of semantic integration in a wide array of meaningful stimuli, including sentences (Fitzpatrick & Indefrey, 2009; Kutas & Hillyard, 1984), pictures (Barrett & Rugg, 1990; Holcomb & McPherson, 1994), and primed visual or auditory words (e.g., Chauncey, Holcomb, & Grainger, 2009; Holcomb, 1993; Holcomb & Neville, 1990). Smaller N400 amplitudes are elicited by congruous and predictable word endings than by incongruous and unexpected endings (Kutas & Hillyard, 1984) because, according to the semantic integration view, less effort and resources are required to integrate congruous and predictable items (Brown & Hagoort, 1993).

Thierry and Wu (2007) demonstrated the influence of one's native language during second-language comprehension by examining the N400 effect in a semantic relatedness task. Chinese-English bilinguals had to decide whether English word pairs were semantically-related. The critical manipulation was that half of the word pairs contained a repeated Chinese character when those words were translated into Chinese. This manipulation was independent of the semantic relatedness of the words and therefore was irrelevant for making semantic judgments in English. The dramatic result was that there was an attenuated N400 when the English word pairs contained the repeated Chinese character irrespective of the meaning relation between the words. Thus, participants were unconsciously accessing the Chinese equivalents of the English words, even though the task was presented in a completely English context. Similar N400 attenuations have been observed for cognates (Midgley, Holcomb, & Grainger, 2011), homophones (Carrasco-Ortiz, Midgley, & Frenck-Mestre, 2012), and interlingual homographs (De Bruijn, Djikstra, Chwilla, & Schriefers, 2001; Hoshino & Thierry, 2012; Kerkhofs, Dijkstra, Chwilla, & de Bruijn, 2006). Interlingual homographs are words that exist in each language system but that carry different meanings across languages, such as the word *pain*, which means "bread" in French. The modulation of the N400 for cross-language manipulations supports the language non-selective model of bilingual language processing, in which bilinguals continue to process the irrelevant lexicon from the non-target language even when performance is restricted to one.

Despite competition from the other language, bilinguals rarely commit cross-language intrusions (Gollan, Sandoval, & Salmon, 2011; Sandoval, Gollan, Ferreira, & Salmon, 2010). Therefore, a mechanism must be employed enabling bilinguals to select the correct language. Green (1998) proposed an inhibitory control model in which a mechanism known as “the specifier” informs the system to activate the linguistic representations of the response language, while suppressing activation from the non-target language. From this continuous need to focus attention on the target language and inhibit the non-target language, bilinguals accumulate extensive practice in selective attention and inhibitory control, both core components of the executive control network. In other words, as a result of managing two languages, bilinguals have developed a more efficient executive control system that could facilitate conflict resolution in other cognitive domains as well (e.g., Bialystok, Craik, Green, & Gollan, 2009).

Bilingualism and Executive Control

A large body of evidence based on word retrieval, object naming, production errors, and tip-of-the-tongue experiences has demonstrated that lexical selection in either language is more effortful for bilinguals than for comparable monolingual speakers of each language (e.g., Gollan & Acenas, 2004; Gollan, Fennema-Notestine, Montoya, & Jernigan, 2007; Gollan, Montoya, Fennema-Notestine, & Morris, 2005; Ivanova & Costa, 2008; Portocarrero, Burright, & Donovick, 2007; Roberts, Garcia, Desrochers, & Hernandez, 2002). For example, highly proficient Spanish-English bilinguals who reported English as their dominant language named pictures in English slower than did English monolinguals (Gollan et al., 2005). Hence, bilinguals are negatively impacted on tasks that assess linguistic abilities.

Despite bilingual disadvantages on linguistic tasks, bilinguals outperform monolinguals on non-verbal tasks requiring conflict resolution, attentional control, inhibitory control, and switching (see Bialystok, 2011 and Bialystok, Craik, & Luk, 2012 for reviews). Such advantages have been reported in a number of studies across the lifespan from infancy (Kovacs & Mehler, 2009) to older age (Bialystok, Craik, Klein, & Viswanathan, 2004; Bialystok, Craik, & Ryan, 2006). For instance, in the Stroop inhibition task, participants are required to name the ink colour of printed words that either match or do not match the ink colour. Because word reading occurs at a faster rate than colour naming (see MacLeod, 1991 for a review), correct colour naming requires the individual to inhibit the natural tendency to say the word rather than the colour. Young and older adult bilinguals required less time than monolinguals to resolve the discrepancy between the competing colour name and ink colour (Bialystok, Craik, & Luk, 2008a). Bilingual advantages were also reported on a children's version of the Stroop task, known as the Shape Stroop task, in 24-month-old toddlers (Poulin-Dubois, Blaye, Coutya, & Bialystok, 2011). In this task, a small picture of a fruit was embedded in a larger picture of a different fruit (e.g., a picture of a small apple in a picture of a big banana). Bilingual children identified the target fruit more often than monolinguals did after being instructed to point to a target picture (e.g., "Show me the small banana"). Together, these findings suggest more efficient conflict resolution resources amongst bilinguals than for comparable monolinguals. Even though bilingualism is a linguistic experience, its benefits appear to extend to other cognitive domains that are important for overall cognitive functioning and information processing.

Hilchey and Klein (2011) pointed out that across a number of executive control tasks, bilinguals are faster than monolinguals on both congruent and incongruent trials. This finding challenges the inhibitory control model by Green (1998) since congruent trials do not require inhibition. For this reason, several researchers have recently favoured conflict monitoring as an explanation for the processing differences between monolinguals and bilinguals (Bialystok, Craik, & Luk, 2012; Costa, Hernández, Costa-Faidella, & Sebastián-Gallés, 2009; Costa, Hernández, & Sebastián-Gallés, 2008; Hilchey & Klein, 2011). The conflict monitoring system is responsible for detecting conflict and for alerting regions associated with attentional control (Botvinick, Braver, Barch, Carter, & Cohen, 2001; van Veen & Carter, 2002). Bialystok et al. (2012) explain that when performing an executive control task, where the number of congruent and incongruent trials is equivalent, there is always the possibility that the subsequent trial will involve conflict. Therefore, prior to engaging conflict resolution processes, a system needs to evaluate each trial for irrelevant information. Individuals with greater attentional control abilities, such as bilinguals, will be able to carry out such evaluations more effectively.

An example of these processes can be seen in the flanker task. The flanker task is an executive control task commonly used to examine inhibitory control processes involved in cognitive control. It has been used to test predictions on the conflict-monitoring hypothesis as well. It is an ideal task to use with event-related potentials because of the minimal number of ocular artifacts that arise. In the flanker task, participants are required to press the left or right key to indicate the direction of the target central arrow. The central arrow is surrounded by distracting arrows that point either in the same direction (e.g., ← ← ← ← ←; congruent condition) or in the opposite direction (e.g., ← ← → ← ←; incongruent condition) as the target arrow. Response times are typically slower in the incongruent condition as a result of two simultaneously primed and contradictory responses, and the additional time required by these trials is termed the "flanker effect". Therefore, the flanker effect serves as an index of the ability to suppress irrelevant information. Previous research with adults has shown that bilinguals are overall faster than monolinguals on both congruent and incongruent trials of the flanker task (Emmorey, Luk, Pyers, & Bialystok, 2008; Luk, Anderson, Craik, Grady, & Bialystok, 2010). Similar results between language groups were found when the flanker interference effect was embedded in an attentional network task (Carlson & Meltzoff, 2008; Costa, Hernández, Costa-Faidella, & Sebastián-Gallés, 2009; Costa, Hernández, & Sebastián-Gallés, 2008). Thus, bilinguals are more adept than monolinguals in selecting the correct response in an array of distracting stimuli.

Costa et al. (2009) investigated the conflict-monitoring hypothesis more directly by manipulating the proportion of congruent and incongruent trials. In the low-monitoring condition (92% congruent and 8% congruent), where there is a greater likelihood that the same type of response will be demanded, monolinguals and bilinguals performed equivalently. However, in the high-monitoring condition (50% congruent or 75% congruent), where the response is less predictable because the number of congruent and incongruent trials is presented more evenly, bilinguals were overall faster than monolinguals. Under circumstances where greater cognitive control and attentional resources are engaged, bilinguals are able to utilize their enhanced executive control abilities to focus on task-relevant aspects of the stimuli.

In the flanker task, the ERP components commonly associated with the interference effect are the N2 and P3. The N2 peaks between 200–350 ms post-stimulus onset at fronto-central electrode sites (Folstein and Van Petten, 2008) and is larger in amplitude for incongruent trials than congruent trials (e.g., Bartholow, Pearson, Dickter, Sher, Fabiani, & Gratton, 2005; Heil, Osman, Wiegelmann, Rolke, & Hennighausen, 2000; Kopp, Rist, & Mattler, 1996). The N2 component has been associated with cognitive control processes, specifically in conflict monitoring (van Veen & Carter, 2002a, 2002b; Purmann, Badde, Luna-Rodriguez, & Wendt, 2011; Yeung, Botvinick, & Cohen, 2004; Yeung & Cohen, 2006) and attentional control processes (Tillman & Wiens, 2011; Bartholow et al., 2005). The second ERP component elicited in the flanker task is the P3, which peaks between 300–600 ms post-stimulus presentation, and is larger in amplitude for the incongruent condition than the congruent condition (Frühholz, Godde, Finke, & Herrmann, 2011). The P3 component has been associated with response inhibition (Frühholz et al., 2011; Neuhaus et al., 2010) as confirmed in a meta-analysis by Nee, Wager, and Jonides (2007) who identified the neural generator of the P3 within the inferior frontal cortex, an area associated with response inhibition.

Brain imaging data from fMRI has shown that monolinguals and bilinguals recruit different areas of the brain when suppressing interference on the flanker task (Luk, Anderson, Craik, Grady, & Bialystok, 2010). While monolinguals activated the left temporal pole and superior parietal cortex for the incongruent trials, bilinguals engaged a more widespread set of regions. Importantly, bilinguals activated regions that coincided with the bilingual language control network posited by Abutalebi and Green (2008). In their review of neuroimaging studies, Abutalebi and Green reported that the left prefrontal cortex, anterior cingulate cortex (ACC), left caudate nucleus, and bilateral supramarginal gyri are activated when managing competing outputs between two active language systems and when exercising cognitive control during non-verbal tasks (i.e., it functions as a cognitive control network for both verbal and non-verbal stimuli). Recently, Abutalebi et al. (2012) examined the link between regions associated with language control and those associated with more general instances of control in monolinguals and highly proficient bilinguals. A language switching task and a flanker task were used. The language switching task for bilinguals consisted of naming a picture in either their first or second language based on a colour cue. Monolinguals, on the other hand, were asked to name a given picture in terms of a verb or a noun based on a colour cue. Activation of the dorsal ACC was reported in both verbal and non-verbal tasks in both groups; however, bilinguals showed less activity in the dorsal ACC than monolinguals. The authors interpreted the difference in activation in terms of the bilingual group being more efficient in adapting to conflict. Therefore, the ACC plays a pivotal role in cognitive control processes across both linguistic and non-linguistic domains.

If bilinguals use the same executive control network for both linguistic and non-linguistic processing, then bilinguals should also demonstrate better performance on linguistic tasks that require conflict resolution. We know from previous research that bilinguals perform poorer on linguistic tasks because of their smaller vocabulary size. But, if the linguistic task required inhibitory control, would the same bilingual advantage observed on non-verbal tasks also extend to linguistic tasks, where we typically find a bilingual disadvantage?

Verbal fluency is an example of a linguistic task that recruits executive control. The task is time-limited and requires rapid lexical retrieval and verbal production. Participants are given 60 seconds to name as many words beginning with a particular letter of the alphabet (letter fluency subtest; e.g., the letter A) or belonging to a specific category (category fluency task; e.g., animals), while avoiding proper nouns, numbers, and variations on the same word. Specifically, the letter fluency subtest places high demands on executive control. According to Luo, Luk, and Bialystok (2010), retrieving words according to phonological attributes is not a common strategy implemented in everyday speech and thus requires more mental effort. Category fluency, on the other hand, places little demands on executive control since individuals routinely access words based on semantic associations.

In past studies, bilinguals have performed similarly to or poorer than monolinguals on letter fluency but consistently poorer than monolinguals on category fluency (Gollan, Montoya, & Werner, 2002; Portocarrero, Burright, & Donovick, 2007; Rosselli, Ardila, Salvatierra, Marquez, Matos, & Weekes, 2002; Sandoval, Gollan, Ferreira, & Salmon, 2010). Not only do bilinguals produce fewer items than monolinguals, but they also require more time to generate the first item. However, most of these studies failed to consider the role of language proficiency on word retrieval by not incorporating any formal measure of vocabulary. It is important to control for vocabulary size given that aggregate analyses on large samples of monolingual and bilingual children (Bialystok, Luk, Peets, & Yang, 2010) and adults (Bialystok & Luk,

2012) reveal that bilinguals on average control a smaller vocabulary than comparable monolinguals of only one of those languages.

The influence of vocabulary size on lexical access was examined by Luo, Luk, & Bialystok (2010), who divided their bilingual group into high-proficiency and low-proficiency bilinguals based on results of a formal English vocabulary test. Accordingly, the high-proficiency bilinguals had a similar vocabulary score as the monolingual group. The high-proficiency bilinguals generated the same number of words as the monolinguals on the category fluency subtest but more words than both the monolinguals and low-proficiency bilinguals on the letter fluency subtest. These results are consistent with a previous study by Bialystok, Craik, and Luk (2008b). Therefore, successful performance on verbal fluency tasks depends on a combination of vocabulary knowledge and executive control.

Within-language competition

Lexical competition is created when speakers must select between similar sounding words or similar word meanings within a language. Studies on lexical access and speech production with monolingual samples reveal that phonological and semantic representations are mutually activated during language processing. For example, Schriefers, Meyer, and Levelt (1990) observed longer naming latencies when a picture was presented with a superimposed word belonging to the same semantic category but shorter naming latencies when a picture was presented with a superimposed word that shared an initial phonological onset. Jerger, Martin, and Damian (2001) replicated these findings with children and teenagers. Schriefers et al. (1990) explained that semantic interference arises because the target lemma and distractor share semantic properties, thus requiring more information in order to discriminate between them. On the other hand, phonologically-related distractors activate the initial phonemes of the target word, which promotes the correct articulation of the appropriate word. Other studies have used eye-tracking technology and the visual-world paradigm to illustrate phonological interference (Allopenna, Magnuson, & Tanenhaus, 1998; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995). When processing a word (e.g., hearing the word "*can*dle"), monolinguals will often briefly look at another object whose name shares a phonemic onset to the target item (e.g., "*can*dy"). Together these findings suggest that semantic and phonological competitors are activated during language processing. However, across these studies, the influence of bilingualism on resolving lexical competition was not explored.

Similar to bilinguals, monolinguals also need to select between linguistic competitors, even though these competitors exist within a single language. Given the established differences between monolinguals and bilinguals in executive control, the expectation is that conflict during lexical selection is handled differently by the two groups. Evidence that lexical conflict resolution processes are different for monolinguals and bilinguals would support the interpretation that managing attention to two languages is different from the within-language competition experienced by monolinguals.

To date, only two studies have investigated whether bilinguals and monolinguals differ in their ability to resolve competition from within-language competitors during auditory comprehension. In an eye-tracking experiment, Blumenfeld and Marian (2011) used a negative-priming paradigm to assess inhibition of phonologically-related pictures on subsequent processing. English monolinguals and highly-proficient English-Spanish bilinguals were presented with four pictures, one at each corner of the screen, which included a target picture (e.g., plum), a phonological competitor (e.g., plug), and two neutral pictures (e.g., ant and candle). Simultaneously, an auditory stimulus named one of the pictures. While eye movements were tracked, participants were required to identify the picture that corresponded to the auditory stimulus. Afterwards, the pictures disappeared and were replaced by three black asterisks and one grey asterisk. The grey asterisk was identified as the probe. Participants had to select the quadrant containing the grey asterisk by pressing one of four keys. When the probe appeared in the same location previously occupied by a phonological competitor, participants generally required more time because that position had been previously inhibited. Despite similar demands on processing, monolinguals identified probes previously occupied by phonological competitors slower than those occupied by neutral pictures, but bilinguals did not differ between the two conditions. The authors interpreted these results to indicate that due to a more efficient control system, bilinguals resolved the interference created by the distractor faster than monolinguals. Furthermore, the degree of lexical activation, measured as the difference in percentage of looks to the phonological picture compared to the neutral pictures, correlated with performance on a Stroop inhibition task for the bilingual group only. This pattern suggests that bilinguals use similar inhibitory mechanisms on both verbal and non-verbal tasks. Therefore, monolinguals and bilinguals differed in their use of inhibition to resolve competition between similar sounding words: bilinguals were more efficient at inhibiting the phonological distractor.

The second study was conducted by Friesen, Rakoczy, and Bialystok (2011), who examined phonological and semantic interference effects in a picture selection task to understand how bilingualism affects conflict resolution processes. In the picture selection task, a pair of pictures is presented, one at each side of a fixation cross, while an auditory stimulus states the name of one of the pictures. Participants are required to press either the left or right mouse key as fast as possible to indicate the location of the named picture. The pairs of pictures are semantically-related, phonologically-related, or unrelated. Successful performance is dependent upon the individual's ability to focus on the target picture while ignoring the relationship between the two pictures. A reaction time cost analysis comparing each interference condition to the unrelated condition revealed no difference between monolinguals and bilinguals in the phonological condition but a significantly reduced cost for bilinguals relative to monolinguals in the semantic condition. In addition, the neurophysiological data revealed that monolinguals exhibited a reduced N400 for both the phonological condition and the semantic condition relative to the unrelated condition, whereas bilinguals did not. This suggests that monolinguals more readily integrated the information from the two pictures than bilinguals. The absence of an attenuated N400, particularly for the semantic condition, in the bilingual group is surprising considering past research has demonstrated such attenuation when participants are presented with two semantically associated pictures, such as fork and knife (Barrett & Rugg, 1990). The authors' interpretation of this effect, in which there is no attenuation for bilinguals, is that bilinguals do not easily integrate two pictures because of the additional lexical competitors that are activated in their second language. The bilingual group requires further exploration in order to determine the underlying mechanism accounting for the differences between monolinguals and bilinguals.

To summarize, there is considerable evidence that the mechanism underlying between-language control in bilinguals is executive control, but less is known about how this mechanism might be involved in the resolution processes of within-language competition. Although Friesen, Rakoczy, and Bialystok (2011) reported electrophysiological differences between monolinguals and bilinguals when resolving within-language lexical competition, it is unclear how these differences arise. In particular for the bilingual group, it is not known how the relation between languages interacts with the within-language competition to produce the results. Since the previous study by Friesen et al. (2011) used a heterogeneous group of bilinguals, who performed the picture selection task in their second language, this question could not be explored. The first goal of the current study was to investigate intralingual and interlingual competition in the same group of participants. Studying a homogeneous group of bilinguals is advantageous for two reasons. The first is that the amount of variability between participants is reduced and second, there is greater precision over which lexical entries are being activated. Hence, the participants for the current study were English-French bilinguals who were tested in each of their languages for interlingual and intralingual conflict on the picture selection task.

Executive control has been proposed as a contributing factor for the differences between bilinguals and monolinguals, however no direct link has been made attributing the bilingual performance to their enhanced executive control. Previous research has also demonstrated that language proficiency influences performance on linguistic tasks. Since the picture selection task is a verbal task, language proficiency could play an important role in selecting the correct lexical representation. Hence, the second goal of the current study was to address whether the factors thought to influence language processing also impact lexical competition resolution processes within and across languages. These factors include executive control, language proficiency, and language production abilities, which were assessed with the flanker task, the Peabody Picture Vocabulary Test, and verbal fluency task, respectively. Positive correlations between the flanker task and the picture selection task would imply that the greater the degree of executive control, the smaller the degree of interference experienced during lexical competition. Moreover, negative correlations between vocabulary measures (i.e., PPVT and verbal fluency scores) and the picture selection task would imply that the greater one's vocabulary knowledge, the smaller the degree of interference experienced by competing lexical entries.

Following the results from the picture selection task by Friesen et al. (2011), it was hypothesized that participants would be slowest on the semantic condition, followed by the phonological-within condition, and then the unrelated condition. At the electrophysiological level, participants should not exhibit an attenuated N400 in the semantic condition and phonological conditions, replicating Friesen et al.'s (2011) findings. With regards to the phonological-between condition, it was hypothesized that an attenuated N400 will be observed, similar to the findings in previous studies on joint activation (e.g., Thierry & Wu, 2007). Behaviourally, participants were expected to be slower to respond in the between-language competition condition than in the unrelated condition, but faster to respond relative to the phonological-within condition. This hypothesis is based on Marian and Spivey's (2003) eye-tracking experiment demonstrating that bilinguals experience competition from both between-language and within-language competition, in which the magnitude is greater for within-language competitors.

Method

Participants

Twenty-six English-French bilinguals between the ages of 17 and 25 years (6 males and 20 females; M_{age} = 20.8 years, *SD* = 2.5) were recruited for two experimental sessions through the York University Undergraduate Research Participant Pool and posters around campus. All participants were right-handed with no history of head injuries, neurological disorders, or auditory problems. Participants had either normal or corrected-to-normal vision. Prior to the first session, participants rated their French speaking abilities in a pre-screen questionnaire. Only those who reported 4 or 5 (1= no proficiency and 5 = very fluent) were selected to participate. Participants received either course credit or monetary compensation ($15 for the first session and $20 for the second session) for their time.

Questionnaires

Language and Social Background Questionnaire (LSBQ; Luk & Bialystok, in press). The LSBQ was used to examine the participant's language use patterns and level of bilingualism (see Appendix A). Participants listed all the languages they know in order of fluency. For each language listed, they indicated the place of acquisition and usage (e.g., home, school, community, work, friends, or travel) and the age of acquisition. Scales were included to determine the participant's self-reported level of proficiency in reading, writing, speaking, and understanding in both English and French (0 = Non-native like to 100 = Native like). Participants indicated their judgment by placing a vertical line along the horizontal scale. In the last section, participants made a global self-assessment on their level of bilingualism by circling a number from 1-5 (1 = monolingual and 5 = fluent bilingual).

French Language Experience Questionnaire (FLEQ). The FLEQ was used to obtain a detailed description of the participant's French language experience, specifically at school (see Appendix B). The first section asked participants to indicate whether they ever lived in a French-speaking community or participated in a French-speaking program abroad. The second section had a chart where participants placed an "X" in each column, from kindergarten to University, to indicate the type of school they attended for each grade. Participants chose from the following: English school (no French course), English school (French course), French school (no English course), French school (English course), French Immersion, and Other. This is especially useful for distinguishing between individuals who attended a French immersion program and those who attended a French school. The last section was to be completed by participants who had previously attended a French immersion program. They were asked to list the courses that were instructed in French from grades 9 to 12 and to rate the overall quality of their immersion program.

Experimental Tasks

Peabody Picture Vocabulary Test – III (PPVT; Dunn & Dunn, 1997). The PPVT is a standardized receptive vocabulary test in English. It is offered in two parallel forms that can be used interchangeably, *Form-A* and *Form-B*. The target words from *Form-B* were translated into French and the PPVT was then used as a measure of French receptive vocabulary knowledge[1]. Using Audacity 2.0, native female speakers of each language recorded the target words at a sampling rate of 44.1 kHz. The sound files were saved as 16-bit WAV files. The PPVT was programmed in E-Prime 2 and presented on a Lenovo ThinkPad x200 Laptop.

Instructions were provided in the target language. For each trial, participants were simultaneously presented with four black-and-white line drawings and an auditory word. Participants selected, using the mouse, the picture that corresponded to the target word. With a computerized converter, raw scores were converted into standard scores using age-based norming tables (μ =100, *SD* =15).

Verbal Fluency (Delis, Kaplan, & Kramer, 2001). In this standardized version of the verbal fluency test, participants are given 60 seconds to generate as many words as possible that start with a given letter (letter fluency task) or belong to a given category (category fluency task). The letter fluency task includes further restrictions that exclude

[1]A French adaptation of the PPVT exists, known as the Échelle de Vocabulaire en Images Peabody (ÉVIP; Dunn, Thériault-Whalen, & Dunn, 1993). However, a number of the items are French-English cognates and the sets do not increase in difficulty like the PPVT. Additionally, Thordardottir, Keheyia, Lessard, Sutton, & Trudeau (2010) found that its published norms underestimate the typical vocabulary of Quebec francophone children and therefore, should be higher than what is currently published. Hence, the ÉVIP was not used in the present study to measure receptive vocabulary in French.

names of people, places, numbers and variations of the same word. Each task was administered twice: once in English for the English session and once in French for the French session. The instructions were provided in the target language. For each language, two letter fluency trials were followed by two category fluency trials. The letter fluency trials were paired as F and A or S and O, and the category trials were paired as animals and clothing or fruits/vegetables and office supplies. The pairs of letters and categories were counterbalanced across languages. All responses were recorded on a Panasonic RR-US551 digital voice recorder for later verification of the words produced. The score for the letter fluency task was the average number of items produced across the two letters, excluding errors and repetitions. The score for the category fluency task was the average number of items produced across the two categories, excluding errors and repetitions. Additionally for the category fluency task, superordinate examplars (e.g., bird) were credited only if no subordinate examplars (e.g., eagle) were produced.

Flanker Task (Eriksen & Eriksen, 1974). The flanker task was programmed in E-Prime v1.2 and presented on a 19-inch Dell 1980 FP Flat Panel computer monitor that was 60 cm away from eye level. Participants were shown a row of five white chevrons at the center of a black screen. Each chevron had a visual angle of 2.66°. A central chevron was surrounded by flanking chevrons that pointed either in the same direction (> > > > > ; congruent trial) or in the opposite direction (< < > < < ; incongruent trial) as the central chevron. Participants used the left or right mouse to indicate the direction of the central chevron as fast as they could.

Each trial began with a blank screen that was presented for 1000 ms, 1250 ms, or

1500 ms, followed by a row of chevrons. The chevrons remained on the screen until a response was made. There were three blocks: the first and third block consisted of 50 congruent trials each and the second block consisted of 100 congruent trials intermixed with 100 incongruent trials, for a total of 300 trials. Participants were given six practice trials before each of the first and second blocks. If needed, participants could extend the number of practice trials, but none of the participants chose to do so. Breaks were provided between each block. Behavioural (RTs and accuracy rates) and electroencephalogram (EEG) data were obtained for this task.

Picture Selection Task. The picture selection task was programmed using E-Prime v1.2 and was administered in English for the English session and in French for the French session. Within each language, 200 black-and-white line drawings were selected from Cycowicz, Friedman, Rothstein, and Snodgrass (1997) and the Internet. The pictures were formatted to be 113 x 113 pixels in size (subtending 5.9˚ in visual angle) and displayed on a white background.

The stimuli for the English version are shown in Appendix C. Forty target pictures (e.g., *Moose*) were paired with one of four types of distractor pictures. The distractor picture was either phonologically-related in English to the target picture (phonological-within condition; e.g., *Moon*), phonologically related in French to the English target picture [phonological-between condition; e.g., *Windmill* (“Moulin” in French)], semantically related to the target (semantic condition; e.g., *Deer*), or unrelated (unrelated condition; e.g., *Sponge*). The stimuli for the French version are shown in Appendix D and consist of the same conditions, except that the names of the pictures are in French. Figure 1 illustrates an example of each condition in the English and French versions. The instructions for each task were provided in the target language.

Word characteristics, such as word frequency, word length, number of phonemes, number of syllables, and neighbourhood size, were retrieved for the name of each picture. The average scores for each statistic per condition are shown in Table 1. The web-based program *N-watch* (Davis, 2005) was used to retrieve the English statistics and *Lexique 2* for the French statistics (New, Pallier, Brysbaert, & Ferrand, 2004). The name of each picture was recorded using Audacity 2.0 by native female speakers of each language at a sampling rate of 44.1 kHz.

Each trial began with a fixation cross displayed at the center of the screen for either 500 ms, 750 ms, 1000 ms, 1250 ms, or 1500 ms. Two pictures were then presented on each side of the fixation cross along with an auditory cue that named one of the pictures. Participants were required to press the left or right mouse key as fast as possible to indicate the location of the named picture. The pictures remained on the screen until a response was made. The target picture and distractor picture were presented on either the left or right side of the fixation cross. Each pair was presented twice: once when the auditory stimulus named the target picture and once when the auditory stimulus named the distractor. Only the trials where the target words were named were analyzed so that each word would serve as its own control. Trials where the non-target picture was named served as filler trials. Participants completed a total of 320 trials and were provided a break halfway through the task. Behavioural (RT and accuracy rates) and electroencephalogram (EEG) data were obtained for this task.

Procedures

Informed consent (Appendix E) was obtained prior to beginning the first testing session. English and French tasks were administered in separate sessions that occurred approximately one week apart. For the French session, all instructions were provided in French. The order of language sessions was counterbalanced across participants. In the first session, regardless of language, participants completed the LSBQ and the FLEQ. Following this, they were administered the other tasks in the following order: Verbal fluency, PPVT, and picture selection task in one language. The same order was used for the second session where tasks were administered in the other language. The flanker task was administered after the English picture selection task regardless of whether English was the first or second testing session. For the electroencephalography (EEG) tasks, the experimenter explained each step while the electrode cap and electrodes were placed on the participant's head. Once the participant was connected to the system, they were shown how eye blinks and muscle tension distorted the EEG signal. This biofeedback step was completed to ensure that the number of artifacts was kept to a minimum. The duration of each session was approximately 90 minutes (including the set-up and removal of the EEG cap). Participants were fully debriefed (see debriefing sheet in Appendix F) about the purpose of the study at the end of the second testing session.

EEG Recordings

Using the BioSemi Acquisition System (BioSemi ActiveTwo, Amsterdam), the electroencephalogram (EEG) was continuously recorded from 64 Ag-AgCl active electrodes that followed the International 10/20 system sites. Six additional electrodes were used: one electrode on each mastoid as a reference for off-line processing, one electrode 1 cm below each eye for measuring vertical electro-oculogram and one electrode placed 1 cm to the left and right of the outer-canthi of each eye for measuring horizontal electro-oculogram. Continuous EEG was recorded at a sampling rate of 512 Hz with a band-pass filter of .01–80 Hz. During the recording, the electrodes were referenced to the common mode sense electrode. Impedances were maintained below 25 μV.

Off-line processing was performed using EEGLAB v11.0.2.1b toolbox under MATLAB v7.14 (2012, Mathworks, Natick, MA). The EEG was re-referenced to the average mastoid measurements and segmented into epochs that were baseline-corrected and stimulus-locked from 200 ms of pre-stimulus activity to 800 ms of post-stimulus activity. Electrode sites with high frequency noise were interpolated. Trials indicative of muscle tension, drift, or head movements were removed prior to conducting the eye artifact detection and rejection procedure using a simple voltage threshold of 400 Hz (English Picture Selection: 0.8% removed; French Picture Selection: 1.1% removed; Flanker: 1.1% removed). Eye movements and eye blinks were detected and corrected using the Independent Components Analysis (ICA; Makeig, Bell, Jung, & Sejnowski, 1996), which has been found to be a valid tool in preserving the brain activity of interest while "filtering" eye artifacts out of the signal (Mennes, Wouters, Vanrumste, Lagae, & Stiers, 2010). ICA reduces the EEG data into a small number of independent components to separate and localize the independent signals in the channel. For each participant, this procedure led to the identification and removal of up to three components that represented an eye blink, a leftward eye movement, a rightward eye movement, and/or a horizontal eye movement. Remaining ocular artifacts were removed using a simple voltage threshold of 150 Hz (English Picture Selection: 3.2% removed; French Picture Selection: 0.2% removed; Flanker 1.0% removed). For each task, individual ERPs were created for each participant by electrode site and condition. These individual ERPs were then averaged within each task and subject to statistical analyses.

Results

Background Measures and Language Profiles

Data from four participants were excluded due to technical difficulties or poor EEG quality. Participants with poor EEG data were identified as those with drift in their EEG signal and those with ocular artifacts remaining in the eye channels even after ICA was performed. An additional participant was excluded because his/her reaction time in two conditions of the English picture selection task was 2.5 SD slower than the group's mean reaction time in those conditions. Hence, the final sample consisted of 21 participants (4 males and 17 females; Mean age = 20.8 years, *SD* = 2.6). Average mother's education level was 3.5 (*SD* = 1.1) on a 5-point Likert scale, which falls in between a college diploma and a bachelor's degree. Participants had a significantly higher PPVT score in English (*M* = 108.2, *SD* = 7.7) than in French (*M* = 100.6, *SD* = 13.1), $t(20) = 3.09$, $p = .006$, 95% CI [2.5, 12.8], $d = 0.67$.[2]

An in-depth language profile of each participant was attained through the Language and Social Background Questionnaire (LSBQ) and the French Language

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[2] It should be noted that the PPVT-B has not been normed on French monolinguals.

Experience Questionnaire (FLEQ). Refer to Table 2 for a breakdown of the participants' language background profile. On the LSBQ, all participants indicated fluency in English and French. Seventeen participants reported fluency in a third language: Arabic (2), Bengali (1), Cantonese (2), Creole (2), Farsi (1), Italian (1), Korean (1), Lingala (1), Malaysian (1), Russian (3), Swahili (1), and Vietnamese (1). Sixteen participants listed English, 4 participants listed French, and 1 participant listed Mauritian Creole (a French-based creole) as the language in which they are most fluent. Participants rated their English and French comprehension, out of 10, as 9.66 (0.8) and 9.21 (1.0), respectively. Additionally, participants rated their English and French speaking abilities, out of 10, as 9.37 (1.3) and 7.21 (1.8), respectively. On a 5-point scale (5 = fluent bilingual), overall level of English-French bilingualism was rated as 4.5 ($SD = 0.6$). Despite the diversity in the participants' language background, with some participants fluent in a third language while others were not, those with a third language rated their fluency in English and French higher than their third language.

For the FLEQ, 18 out of 21 participants indicated they had spent some time living in a French-speaking country or community. Twelve participants had attended a French immersion program until grade 12 (with the exclusion of one participant who switched from the French immersion program to CORE French in grade 6). Seven participants had attended a French school until grade 12 where the instructions for all courses were provided in French. The remaining two participants indicated they went to an English school without taking any French courses; however, both participants lived in a French-speaking community until University (Quebec and Mauritius). Despite varied experiences with French, all participants communicated effectively with the experimenter in French during the French testing session.

Behavioural Results

Picture Selection Task. The data trimming procedure consisted of removing trials that were +/- 2.5 SDs from the participant's average within each condition (2.6% removed for the English version and 2.6% removed for the French version). Mean reaction times of correct responses and accuracy rates by distractor type and language are presented in Table 3.

The accuracy rates ranged from 90%–99% for the English picture selection task and from 89%–98% in the French picture selection task. No statistical analyses were conducted on the accuracy rates due to the lack of variance. Since accuracy rates were already high, all differences observed in response time could not be attributed to speed-accuracy trade-off.

A two-way ANOVA was conducted on RTs with language (English vs. French) and distractor type (unrelated, semantic, phonological-within, and phonological-between) as within-subject factors. Post-hoc comparisons were conducted using the Bonferroni correction on significant main effects. There was a main effect of distractor type, $F(3,60) = 120.40$, $p < .001$, $\eta_p^2 = .86$, in which semantically-related pictures produced longer response times than phonologically-related pictures ($p < .001$, $d = 2.84$), phonologically-related pictures across languages ($p < .001$, $d = 2.48$), and unrelated pictures ($p < .001$, $d = 2.86$). The main effect of language was not significant, $F(1,20) = 2.39$, $p = .14$, $\eta_p^2 = .11$, but there was a marginal language by distractor type interaction, $F(3,60) = 2.73$, $p =$

.070, η_p^2 = .12. Paired-samples t-tests comparing the English and French version revealed that when the pictures were phonologically-related across languages, participants were faster in English than in French, *t*(20) = 3.08, *p* = .006, 95% CI [14.0, 72.6], *d* = 0.66.

To examine the degree of interference from semantically-related, phonologically-related within the same language, and phonologically-related between languages pictures relative to unrelated pictures, cost scores were computed. Cost scores were the difference in RT between the unrelated condition and each of the related conditions (semantic cost RT = semantic RT – unrelated RT; phonological-within cost RT = phonological-within RT – unrelated RT; phonological-between cost RT = phonological-between RT – unrelated RT). Figure 2 displays the cost scores by distractor type and language. These cost scores were analyzed in a language (English vs. French) by distractor type cost (semantic cost, phonological-within cost, and phonological-between cost) repeated-measures ANOVA. There was a main effect of distractor type cost, *F*(2,40) = 124.09, *p* < .001, η_p^2 = .86, in which there was greater cost in the semantic condition than in the phonological-within condition (*p* < .001, *d* =2.84) and phonological-between condition (*p* < .001, *d* = 2.48). The effect of language was not significant, *F*(1,20) = .16, *p* = .70, η_p^2 = .01. There was a significant language by distractor type cost interaction, *F*(2,40) = 3.59, *p* = .037, η_p^2 = .15. The pattern was such that for the phonological-within and phonological-between conditions, there was a larger cost in French than in English. However, for the semantic condition, there was a larger cost in English than in French. Despite such patterns, the differences between languages for the phonological-within [*t*(20) = 0.33, *p* = .74, 95% CI [-23.0, 31.6], *d* =.07], phonological-between, [*t*(20) = 0.99, *p* = .34, 95% CI [-17.3, 48.4], *d* =.22], and semantic cost condition [*t*(20) = -1.55, *p* = .14, 95% CI [23.0, -83.8], *d* =-0.34] were not statistically significant.

Picture Selection Task and Language Dominance. The influence of language dominance was examined on performance in the picture selection task. Language dominance was determined as the first language listed in order of fluency by participants on the LSBQ. Four participants indicated French as their most fluent language and 17 indicated English. For both the English and French picture selection task, independent samples t-tests were conducted on the RTs and cost RTs with language dominance as a between-subjects variable (Table 4). There were no significant differences between groups, all *p*s > .05.

Picture Selection Task and Fluency in a Third Language. The influence of a third language was examined on performance in the picture selection task. Four participants were fluent in only English and French, while the remaining 17 participants were fluent in a third language. For both the English and French picture selection task, independent samples t-tests were conducted on the RTs and cost RTs with fluency in a third language as a between-subjects variable (Table 5). There were no significant differences between groups, all *p*s > .05.

Flanker Task. The data trimming procedures consisted of removing reaction times +/- 2.5 SDs from the individual's mean for each trial type (2.5% removed). Mean reaction times of correct responses and accuracy rates by trial type are presented in Table 6. The congruent trials from blocks one and three were combined and labeled as "congruent pure trials".

The accuracy rates for all conditions in the flanker task ranged from 94%–99%. No statistical analyses were conducted on accuracy rates due to the lack of variance. Since accuracy rates were already high, all differences observed in response time could not be attributed to speed-accuracy trade-off.

Participants were faster when the congruent condition was presented in the pure block than in the mixed block, $t(20) = 4.37$, $p < .001$, 95% CI [20.8, 58.8], $d = 0.95$. The difference between these two conditions is the mixing costs (mixing costs = congruent mixed RT – congruent pure RT). In the mixed block, there was an effect of congruency, with faster RT for congruent than incongruent trials, $t(20) = 9.79$, $p < .001$, 95% CI [39.0, 60.1], $d = 2.14$. The difference between these two conditions within the mixed block is the flanker effect (flanker effect = incongruent mixed RT – congruent mixed RT).

Verbal Fluency. The mean number of words produced in each fluency task by language is presented in Table 7. A 2-way ANOVA with language (English vs. French) and fluency task (letter vs. category) as within-subject factors, showed a main effect of language, $F(1,20) = 30.53$, $p < .001$, $\eta_p^2 = .60$. Participants generated more words in English ($M = 14.3$, $SD = 4.8$) than in French ($M = 10.4$, $SD = 3.8$), $p < .001$, $d = 1.20$. There was also a main effect of fluency task, $F(1,20) = 83.31$, $p < .001$, $\eta_p^2 = .81$. Participants produced more words for category fluency ($M = 15.0$, $SD = 4.7$) than for letter fluency ($M = 9.7$, $SD = 3.0$), $p < .001$, $d = 2.00$. The language by fluency task interaction did not reach significance, $F(1,20) = 1.56$, $p = .23$, $\eta_p^2 = .07$.

Correlations. Correlations were conducted for each condition of the picture selection task with an overall measure of the flanker task, the incongruent condition from the flanker task, letter fluency score, category fluency score, and PPVT score. The overall measure for the flanker task was computed by taking an average of the mean reaction time from the congruent pure, congruent mixed, and incongruent mixed conditions from the flanker task. These correlations by language are shown in Table 8. Each condition from the English picture selection task correlated positively with the overall measure of the flanker task (ps < .01) and with the incongruent condition from the flanker task (ps < .01). Each condition from the French picture selection task correlated positively with the overall measure of the flanker task (ps < .05) and negatively with the category fluency task (ps < .05). Additionally, the phonological-within and phonological-between conditions in the French picture selection task correlated positively with the incongruent condition from the flanker task (ps < .05), whereas the semantic and unrelated conditions correlated negatively with the French PPVT score (ps < .05).

Correlations were conducted between the costs scores from the picture selection task with the flanker effect and mixing costs from the flanker task (Table 9). In English and French, the flanker effect did not correlate with any of the cost conditions from the picture selection task. However, the mixing costs correlated with the French phonological-within cost condition only ($r = .53$, $p = .013$).

Electrophysiological Results

Picture Selection Task. ERP analyses on the N400 component were conducted on the mean amplitudes of correct responses between 400–550 ms post-stimulus onset. Measurements were taken from 12 electrode sites (FC1, FCz, FC2, C1, Cz, C2, CP1, CPz, CP2, P1, Pz, and P2) across the scalp that were arranged in a 3 lateral by 4 anterior-posterior grid. A four-way ANOVA with language (English vs. French), distractor type (unrelated, semantic, phonological-within, and phonological-between), laterality (left lateral, medial, and right lateral electrode sites), and anteriority (fronto-central, central, central-parietal, and posterior electrodes) as within-subject factors was performed. The Greenhouse-Geisser correction was applied to variables with more than one degree of freedom in the numerator. Post-hoc analyses were conducted for all significant main effects and interactions.

The analysis for the N400 yielded no significant effects of language, $F(1,20) = .75$, $p = .40$, $\eta_p^2 = .04$, distractor type, $F(3,60) = .91$, $p = .42$, $\eta_p^2 = .04$, or distractor type by language interaction, $F(3,60) = .12$, $p = .94$, $\eta_p^2 = .006$. However, there was a main effect of laterality, $F(2,40) = 5.43$, $p = .02$, $\eta_p^2 = .21$, and anteriority, $F(3,60) = 41.21$, $p < .001$, $\eta_p^2 = .67$, in which there was greater negativity at the frontal-central electrodes and at the midline electrodes. There was also a significant anteriority by laterality interaction, $F(6,120) = 3.19$, $p = .024$, $\eta_p^2 = .14$. The frontal-central, central, and central-parietal sites elicited greater negativity in the midline electrodes compared to the lateral electrode sites (all *p*s < .05). However, for the posterior electrodes, the midline electrode was significantly more negative from the left lateral electrode ($p = .014$) but not the right lateral electrode ($p = .78$). No other interactions reached significance. The grand average ERPs for all conditions are shown in Figure 3.

Of particular interest is how each of the related distractors is processed relative to the unrelated distractor. Hence, the semantic, phonological-within, and phonological-between conditions were each compared separately to the unrelated condition in three separate four-way repeated-measures ANOVAs. The within-subject factors included language (English vs. French), distractor type (semantic vs. unrelated, phonological-within vs. unrelated, or phonological-between vs. unrelated), anteriority (fronto-central, central, central-parietal, and posterior electrodes), and laterality (left lateral, medial, and right lateral). The grand average ERPs for the semantic distractor, phonological-within distractor, and phonological-between distractor analyses are shown in Figures 4, 5, and 6, respectively. The Greenhouse-Geisser correction was applied to variables with more than one degree of freedom in the numerator. Post-hoc analyses were conducted for all significant main effects and interactions.

The semantic distractor analysis (semantic versus unrelated) revealed no effect of language, $F(1,20) = .64$, $p = .44$, $\eta_p^2 = .03$, distractor type, $F(1,20) = .26$, $p = .62$, $\eta_p^2 = .01$, or language by distractor type interaction, $F(1,20) = .33$, $p = .57$, $\eta_p^2 = .02$. However, there was a main effect of laterality, $F(2,40) = 5.41$, $p = .018$, $\eta_p^2 = .21$, and anteriority, $F(3,60) = 37.48$, $p < .001$, $\eta_p^2 = .65$, in which there was greater negativity in the frontal-central electrodes and at the midline electrodes. The interaction between distractor type and laterality was significant, $F(2,40) = 6.00$, $p = .014$, $\eta_p^2 = .23$. The semantic and unrelated condition both elicited greater negativity in the midline electrodes relative to the lateral electrode sites, but this was more pronounced for the semantic condition (*p*s < .01) than unrelated condition (*p*s < .036). Lastly, there was a significant anteriority by laterality interaction, $F(6,120) = 3.25$, $p = .024$, $\eta_p^2 = .14$. The fronto-central, central, and central-parietal electrode sites elicited greater negativity at the midline electrodes compared to the lateral electrode sites (*p*s > .033). However, in the posterior electrode sites, the midline electrode was significantly more negative than the left lateral electrode (p = .028) but not the right lateral electrode (p = .24). No other interactions reached significance.

The phonological-within distractor analysis (phonological-within versus unrelated) yielded no effect of language, $F(1,20) = 1.33$, $p = .26$, $\eta_p^2 = .06$, distractor type, $F(1,20) = 1.55$, $p = .23$, $\eta_p^2 = .07$, or language by distractor type interaction, $F(1,20) = .14$, $p = .71$, $\eta_p^2 = .007$. There was a significant main effect of laterality, $F(2,40) = 6.44$, $p = .012$, $\eta_p^2 = .24$, and anteriority, $F(3,60) = 37.62$, $p < .001$, $\eta_p^2 = .65$, in which greater negativity was elicited at frontal-central electrodes and at the midline electrodes. Furthermore, the interaction between anteriority and laterality was significant, $F(6,120) = 2.89$, $p = .045$, $\eta_p^2 = .13$. At the central-parietal electrode sites, the midline electrode was significantly more negative than the lateral electrode (ps < .004). At the fronto-central, central, and posterior electrode sites, the midline electrodes were only significantly different from the left lateral electrodes (all ps < .009), but not the right lateral electrodes (all ps > .05). No other interactions reached statistical significance.

The phonological-between distractor analysis (phonological-between versus unrelated) revealed no effect of language, $F(1,20) = .90$, $p = .36$, $\eta_p^2 = .04$, distractor type, $F(1,20) = .39$, $p = .54$, $\eta_p^2 = .02$, or language by distractor type interaction, $F(1,20) = .02$, $p = .892$, $\eta_p^2 = .001$. However, there was a significant main effect of laterality, $F(2,40) = 6.24$, $p = .013$, $\eta_p^2 = .24$, and anteriority, $F(3,60) = 42.99$, $p < .001$, $\eta_p^2 = .68$, in which greater negativity was elicited in the frontal-central electrodes and at the midline electrodes. Furthermore, the interaction between anteriority and laterality was significant,

$F(6,120) = 2.90$, $p = .029$, $\eta_p^2 = .13$. At the central-parietal electrode sites, the midline electrode was significantly more negative than the lateral electrodes (*p*s < .004). At the fronto-central, central, and posterior electrode sites, the midline electrodes were only significantly different from the left lateral electrodes (all *p*s < .006), but not the right lateral electrodes (all *p*s > .05). No other interactions reached significance.

In summary, the N400 amplitude did not differ by distractor type in either English or French. When separate analyses for the semantic and phonological effects (within and between) were conducted, the difference in the N400 amplitude between each interference condition relative to the unrelated condition did not reach significance. The largest differences in mean amplitude between each of the related conditions compared to the unrelated condition were found at electrodes CPz and Pz. The interaction between anteriority and laterality revealed that the two phonological conditions (and the semantic condition to a lesser extent), when compared to the unrelated condition, had an N400 effect that was largest at the midline and right lateral electrodes. This is consistent with the literature on the N400 effect, where the N400 amplitude is typically largest at central-parietal electrodes and has a slight right hemisphere bias (see Kutas & Federmeier, 2011 for a review).

Flanker Task: ERP mean amplitude analyses. Consistent with previous ERP literature on the flanker task, a frontal N2 was observed between 200–350ms as well as a central-parietal P3 between 300–500ms post-stimulus onset. Electrode sites Fz, FCz, and Cz were selected in the analysis of the N2 component, while electrode sites Cz, CPz, and Pz were selected for the analysis of the P3 component. Midline electrodes were selected for analysis based on previous research demonstrating that the N2 and P3 effects are focal over medial locations (e.g., Nieuwenhuis, Yeung, Van Den Wildenberg, & Ridderinkhof, 2003). Congruency (congruent mixed versus incongruent mixed) and block (congruent pure versus congruent mixed) were analyzed separately for each component. Thus, the ANOVA consisted of congruency or block as a within-subjects factor and electrode site as another within-subjects factor. The grand averaged ERPs with the N2 and P3 components highlighted for the effects of congruency and block are shown in Figures 7 and 8, respectively.

The N2 component indexes conflict monitoring and attentional processes and is maximal over frontal-central electrode sites. For the analysis of block (congruent pure versus congruent mixed) in the 200–350 ms time window, there was a main effect of block, $F(1,20) = 14.20$, $p = .001$, $\eta_p^2 = .42$, in which the congruent condition in the mixed block (μV = .96) was more negative in amplitude than the congruent condition in the pure block (μV = 2.39), $p = .001$. There was also a main effect of electrode, $F(2,40) = 4.89$, $p = .036$, $\eta_p^2 = .20$, in which electrode FCz (μV = 1.65) was marginally more negative than electrode Cz (μV = 2.28), $p = .08$. Lastly, there was a block by electrode interaction, $F(2,40) = 5.09$, $p = .031$, $\eta_p^2 = .20$, such that at each electrode site, the difference between the congruent pure and congruent mixed condition was significant (all *p*s < .005), with the largest differences between conditions observed at electrodes FCz and Cz (*p*s < .001).

For the analysis of congruency (congruent mixed versus incongruent mixed) for the N2 component in the 200–350 ms time window, there was no effect of congruency,

F(1,20) = 1.83, p = .19, η_p^2 = .08. There was a marginal effect of electrode, F(2,40) = 3.97, p = .058, η_p^2 = .17, in which electrode FCz (μV = .50) was marginally more negative than electrode Cz (μV = 1.12), p = .071. The congruency by electrode interaction did not reach significance, F(2,40) = .26, p = .65, η_p^2 = .01.

The P3 component, which is an index of response inhibition, is maximal over central-parietal electrode sites. Since no inhibition is required for the congruent condition, the analysis for the P3 component was conducted for the flanker effect and not the mixing costs. For the analysis of congruency in the P3 time window, 300–500ms, there was no effect of congruency, F(1,20) = .45, p = .51, η_p^2 = .02. However, there was a main effect of electrode, F(2,40) = 8.36, p = .008, η_p^2 = .30, in which electrode Cz (μV = 3.79) was significantly less positive than electrode CPz (μV = 4.73), p = .008, and Pz (μV = 5.30), p = .026. The congruency by electrode interaction did not reach significance, F(2,40) = 1.68, p =.21, η_p^2 = .08.

Brain-Behaviour Correlations. For each condition of the picture selection task, the N400 mean amplitude of electrode CPz was correlated with its respective behavioural reaction time data. None of the brain-behaviour correlations for the N400 component reached statistical significance (Table 10). Furthermore, ERP amplitude differences were calculated as the difference between the mean amplitudes of electrode CPz for each of the related conditions from the unrelated condition. The ERP amplitude differences were then correlated with their respective behavioural reaction time cost data. None of the cost brain-behaviour correlations for the N400 component reached statistical significance (Table 11).

For the flanker task, brain-behaviour correlations were conducted using the mean amplitudes of electrode FCz for the N2 component and CPz for the P3 component and correlating each with its respective behavioural data. Brain-behaviour correlations for the P3 component were performed with the incongruent condition only since the congruent condition does not require inhibition, which the P3 component indexes. None of the brain-behaviour correlations in the N2 time window correlated with their respective behavioural data. In contrast, the incongruent condition in the P3 time window correlated with its respective behavioural data (r =-0.46, p = .043; Table 12). Furthermore, ERP amplitude differences were computed for the flanker effect by taking the difference in mean amplitudes between the congruent mixed condition and the incongruent mixed condition in electrode FCz for the N2 component and CPz for the P3 component. These were then correlated with their respective behavioural reaction time cost. There were no significant correlations between the ERP amplitude differences of the flanker effect in the N2 and P3 components and their respective behavioural flanker effect (Table 13). ERP amplitude differences were computed for the mixing costs by taking the difference in mean amplitudes between the congruent pure condition and the congruent mixed condition in electrode FCz for the N2 component. These were then correlated with their respective behavioural reaction time cost. There were no significant correlations between the mixing costs ERP amplitude differences in N2 with its respective behavioural mixing costs.

Correlations between the ERP flanker task and ERP picture selection task. Correlations between each version (English and French) of the picture selection task with the flanker task for all time windows of interest were conducted for the ERP mean amplitudes (Table 14) and ERP mean amplitude differences (Table 15). In the English picture selection task, the P3 amplitude of the incongruent mixed condition correlated positively with the N400 ERP amplitude of the unrelated condition ($r = .45$, $p = .042$). Additionally, the P3 amplitude difference for the flanker effect correlated negatively with the N400 amplitude difference of the phonological-between cost condition of the English picture selection task ($r = -.44$, $p = .047$). No other correlations reached statistical significance.

Discussion

The current study investigated the role of executive control, language proficiency, and language production abilities in resolving lexical competition within a single language and across languages. No research to date has examined the behavioural and neural correlates of both intralingual and interlingual conflict resolution in a single study, even though bilingual language processing is impacted by both. To address this gap in the literature, the cortical activity of highly proficient English-French bilinguals was recorded while participants performed the picture selection task in each of their languages. Across both languages, four main findings were observed. First, English-French bilinguals were slower to identify the target picture when it was presented with a semantic distractor than when it was presented with a phonological or unrelated distractor. Second, the phonological-between condition, which was used to index cross-language activation, did not differ significantly from the unrelated condition. Third, in the N400 time window, there was no difference in amplitude across the different distractor pairs in either English or French, indicating no integration of the two stimuli. Fourth, there was no evidence for a relation between the efficiency of executive control used to perform the picture selection task and performance on a nonverbal conflict task, namely, the flanker task. However, there was a relation between vocabulary knowledge and the picture selection task only when participants performed the task in their less dominant language, French. French was determined as the weaker language based on the smaller PPVT score, letter fluency score, and category fluency score relative to English.

On the flanker task, longer response times and greater N2 and P3 amplitudes for the incongruent trials compared to the congruent trials were found, which is consistent with previous behavioural (Emmorey, Luk, Pyers, & Bialystok, 2008; Luk, Anderson, Craik, Grady, & Bialystok, 2010) and ERP (N2: e.g., Bartholow, Pearson, Dickter, Sher, Fabiani, & Gratton, 2005 and P3: e.g., Frühholz, Godde, Finke, & Herrmann, 2011) studies on the flanker effect. Thus, the incongruent condition is associated with increased conflict monitoring and attentional control, represented by the frontal-central N2 component, as well as increased processing in response suppression, as represented by the central-parietal P3 component. The mixing cost was evaluated by comparing the congruent condition in the pure block to the congruent condition in the mixed block. When the congruent condition was presented alone, faster response times and smaller N2 amplitudes were elicited compared to the congruent condition presented in the mixed block. This implies that when the congruent condition is intermixed with the incongruent condition, greater conflict monitoring processes are engaged due to the possibility that at any time the incongruent condition may be presented. Therefore, performance on the flanker task is dependent upon inhibitory control, as well as other components of the executive control system, such as attentional control and conflict monitoring.

Consistent with the literature, participants produced more words for category fluency than letter fluency (e.g., Luo, Luk, & Bialystok, 2010) and in their dominant language (English) relative to their less dominant language (French). More words were generated in category fluency because, according to Luo et al. (2010), we often retrieve words based on semantic membership rather than phonology. Less words are produced in the less dominant language due to the inability to inhibit interference from the second language that competes for recognition and selection (Hermans, Bongaerts, de Bot, & Schreuder, 1998) and because more time is required to produce words in the second language (Chen & Leung, 1989).

The behavioural results from the picture selection task indicate that participants experienced greater interference from two semantically-related pictures than from two phonologically-related pictures. The semantic distractor produced a significant cost relative to unrelated items, replicating the findings from Friesen et al. (2011) who used essentially the same task with a mixed group of bilinguals and monolingual participants. Such findings are consistent with previous work on the semantic interference effect (Jerger, Martin, & Damian, 2001; Schriefers, Meyer, & Levelt, 1990), in which longer naming latencies are observed for pictures that are presented simultaneously with a semantically-related stimulus. In contrast, when the distractor picture shared a phonological onset with the target picture, the cost relative to the unrelated distractor was not significant. The unexpected finding showing no interference in the present study contradicts most of the literature with monolingual and bilingual samples in which phonological competitors increase reaction time (Blumenfeld and Marian, 2011; Friesen, Rakoczy, & Bialystok, 2011). However, the difference in phonological cost RT between the heterogeneous group of bilinguals in Friesen, Rakoczy, and Bialystok's (2011) study and that from the present study was only 17 ms. Together these findings indicate that selecting between pictures that are semantically-related is more cognitively demanding than selecting between phonologically-related pictures, with the additional effort required for phonological competition to be smaller and more variable.

Why would a semantic distractor require more effort than a phonological distractor when each is presented with the same target picture? The difference may lie in the strength and degree of lexical activation that each competitor elicits. In the case of the phonological competitor, the cohort model by Marslen-Wilson and colleagues (e.g., Marslen-Wilson & Welsh, 1978) explains that the onset of a word activates a set of lexical candidates that compete for recognition. For example, as the word *cabbage* is heard, both *cabbage* and *cabinet* become active members of the recognition cohort. The activation reduces once mismatches are detected over time between lexical candidates and the ongoing speech. Thus, the activation of the word *cabinet* would begin to decline at the second phoneme because the auditory input is no longer consistent with the target word. However, in the case of the semantic competitor, models on lexical access (e.g., Starreveld & La Heij, 1995) explain that a target word's semantic representation (e.g., DOG) automatically activates the lexical nodes from members of the same category (e.g., CAT). If the semantic distractor is CAT, it receives activation not only from the auditory target word DOG but also from its own representation. The conflict diminishes once the individual successfully overcomes the activation from the semantic distractor. Hence, lexical access and selection between phonologically-related items is achieved with greater ease than semantically-related items.

It may be argued that the semantic condition was more difficult than the phonological and unrelated conditions simply because semantic pairs tend to also be visually similar, making the discrimination more difficult. To control for this alternative explanation, 24 individuals rated each semantic pair on a 5-point scale (1 = no visual similarity and 5 = high in visual similarity). The instructions emphasized the need for the judgments to be made purely based on the visual characteristics of the pictures. By averaging across judgments, a visual similarity rating was obtained for each semantic pair. A median split was conducted comparing the 20 pairs with the highest ratings to the 20 pairs with the lowest ratings. There was an RT increase of 224 ms for the English version and 155 ms for the French version for the 20 most visually similar pairs compared to the 20 least visually similar pairs (Table 15). Moreover, the semantic cost RTs correlated positively with the visual similarity ratings in English (r = .64, $p < .001$) and French (r = .55, $p < .001$), implying that the more visually similar two semantic pictures were the greater the degree of semantic interference. Therefore, visual similarity is a contributing factor for the behavioural results observed in the semantic condition.

The role of visual similarity on the semantic interference effect has been investigated in picture naming studies (Damian, Vigliocco, & Levelt, 2001; Hocking, McMahon, de Zubicaray, 2009) and picture categorization studies (Lotto, Job, &

Rumiati, 1999; Snodgrass & McCullough, 1986). For example, Damian et al. (2001) had participants name pictures that belonged to a particular category that were all low in visual similarity (e.g., mouse, spider, snake, fish, and duck). Similarly, Hocking et al. (2009) directly compared items low and high in visual similarity within the same picture-naming paradigm as Damian et al. (2011). In both studies, the semantic interference effect occurred independently of whether the semantic items shared similar visual features. Both set of researchers concluded that the increased naming latencies for semantic items occurred as a result of competition among co-activated lexical entries by virtue of their semantic relatedness and not from competition of the overlapping visual features. In contrast, performance on categorization tasks reveal that participants were slower to make manual responses when classifying objects belonging to the same category that were visually similar compared to those intermixed with visually dissimilar items (Lotto et al., 1999; Snodgrass & McCullough, 1986). The picture selection task also requires a manual response to be made, which could be the reason why visual similarity was a contributing factor. It is difficult to rule out visual similarity as a potential confound for the semantic condition when presenting stimuli visually. Even if measures were taken to minimize the degree of visual similarity among semantic pairs, these items would still be perceived to be more visually similar than the items that are unrelated.

Interlingual competition was assessed with the phonological-between condition, in which target picture’s name was phonologically-related to the distractor picture’s translation. The behavioural results from the phonological-between condition indicate little interference from the non-target language. Contrary to previous behavioural studies (e.g., Costa, Colomé, Gómez, & Sebatián-Gallés, 2003; Hermans, Bongaerts, de Bot, & Schreuder, 1998), the phonological-between condition did not significantly differ in RTs from the unrelated condition. In fact, the RTs for the English phonological-between condition and the unrelated condition were exactly the same.

Cross-linguistic activation between the first and second language varies depending on the relative proficiency of the bilinguals as well as the language context tested (purely L1, purely L2, or mixed; see Kroll, Bobb, & Wodniecka, 2006 for a review). A majority of the behavioural studies investigating cross-language activation were conducted under the picture-naming interference paradigm with bilinguals performing the task in their less dominant language (e.g., Costa, Colomé, Gómez, & Sebatián-Gallés, 2003; Hermans, Bongaerts, de Bot, & Schreuder, 1998). In a review by Kroll, Bobb, Misra, and Guo (2008), the authors explain that on verbal production tasks in the dominant language, there is little evidence of the less dominant language because the time course of speech planning in L1 is much more rapid, leaving little room for L2 to emerge. However, in the less dominant language, there are multiple influences of L1 on L2 processing. The current study had participants perform the task in both of their languages, including their dominant language. Based on the behavioural results from the phonological-between condition, there is greater interference of the dominant language into the less dominant language, but the influence of the less dominant language into the more dominant language was not found.

The language context participants are tested in also influences the degree of cross-language activation. In Costa, Colomé, Gómez, & Sebatián-Gallés (2003) and in the second experiment by Hermans, Bongaerts, de Bot, & Schreuder (1998), participants named target pictures in their L2 while ignoring distractors from their L1. The language context within this task is such that both languages are required. Participants are thus aware that both of their languages are being evaluated. Therefore, both languages are strongly activated. In the current study, the English and French sessions were conducted one week apart and the instructions were provided in the target language. The testing session is in a single-language context, which is less likely to promote activation of the non-target language.

The only difference observed between the English and French version of the picture selection task was in the behavioural data of the phonological-between condition. The larger cost for the phonological-between condition in French than in English provides support for English as the dominant language. Considering that the majority of participants were English dominant and immersed in an English environment (York University is an English-dominant university), French may have been too weak to interfere with processing in English. The significant correlation for the French phonological-between condition and French vocabulary illustrates that this is a calibrated effect. As proficiency in French increases, there is reduced interference from the English language when performing in French. On the other hand, differences between languages were not found for the electrophysiological data, implying similar lexical competition resolution processes in English and French at the cortical level.

The process by which participants decided between the two stimuli was also indicated by the electrophysiological data. In studies involving lexical decision, the ERP shows a modulation of the amplitude in N400 indicating integration of semantically-related stimuli (Anderson & Holcomb, 1995; Chwilla, Brown, & Hagoort, 1995; Holcomb & McPherson, 1994), phonologically-related stimuli within the same language (Praamstra, Meyer, & Levelt, 1994), and stimuli related across languages (de Bruijn, Djikstra, Chwilla, & Schriefers, 2001; Hoshino & Thierry, 2012; Kerkhofs, Dijkstra, Chwilla, & de Bruijn, 2006; Midgley, Holcomb, & Grainger, 2011). The surprising finding in the present study is that there was no such modulation of the N400 in either language for the semantic, phonological-within, phonological-between, and the unrelated conditions. This is the same pattern reported by Friesen, Rakoczy, and Bialystok (2011) in their heterogeneous group of bilinguals. In contrast, the monolingual group in their study demonstrated the expected N400 attenuation for the semantic and phonological condition. The authors interpreted the monolingual findings to reflect that monolinguals automatically processed the relationship between pictures, consequently integrating the two items. Integration of the two pictures hinders performance on the picture selection task as it increases the difficulty to discern and identify the target picture among the related pictures. Therefore, there are electrophysiological differences between monolinguals and bilinguals in how each group resolves lexical competition. The question is, what is unique about bilingualism that enables them to manage lexical conflict differently than monolinguals?

What can account for the lack of an N400 attenuation in the bilingual group? Do bilinguals simply not integrate semantic information? This is unlikely since McLaughlin, Osterhout, and Kim (2004) found after only 14 hours of university-level instruction in French, second-language learners produced smaller N400s in their second language to words accompanied by semantically-related words relative to target words accompanied by unrelated words. Thus, the lack of a reduction in N400 for bilinguals cannot be due to the nature of their semantic representations, especially considering the fact that their English and French vocabulary knowledge were above the norm.

One explanation for the electrophysiological data lies in the architecture of the bilingual lexicon. During language processing, bilinguals face greater ambiguity than monolinguals because they consider similar-sounding and similar-meaning words from two languages. Since bilinguals have both languages active and more competitors for every decision, there is always conflict elicited and less grounds for integration. Hence, in the picture selection task, bilinguals activated the lexical representations for both pictures in the target language as well as in the non-target language. Moreover, a number of lexical candidates that overlapped in phonological and semantic features with those representations were also activated. For this reason, the relationship between the two pictures was less automatic for integration to take place.

Alternatively, the electrophysiological data can be interpreted in terms of what creates the N400 component. Past research has shown that the N400 is larger for semantically anomalous items (Kutas & Hillyard, 1984). Considering that the picture selection task consists of a triad of stimuli (an auditory cue, a target picture that matches the auditory cue, and lastly a distractor picture that does not match the auditory cue), it is possible that for bilinguals, the semantic associations between all three stimuli are weak because of the number of contenders that exist in the other language that are also activated and competing for selection. For this reason, there is no observed reduction of the N400 for the bilinguals since there is greater ambiguity in determining which picture matches the auditory cue. However, for the monolinguals, the association between two of the three stimuli is so strong that the N400 in the semantic condition is reduced compared to the N400 in the unrelated condition.

Despite experiencing greater conflict, bilinguals perform the task more efficiently than monolinguals (as evident in the smaller semantic RT cost incurred for bilinguals than monolinguals in Friesen, Rakoczy, & Bialystok, 2011). Therefore, bilinguals may have developed a more efficient mechanism than monolinguals for managing conflict from all linguistic sources (intralingual and interlingual), implying that the added interference from the second language and managing both between-language and within-language competition by bilinguals is different than managing within-language competition alone. Given the complex nature of bilingual lexical access and language processing, the bilingual's skillful ability to select between intralingual and interlingual competitors is impressive.

Since both monolinguals and bilinguals are required to recruit executive control to manage the lexical conflict elicited in the picture selection task, it was important to investigate the role of executive control in resolving lexical competition for bilinguals. The picture selection task is challenging, especially when the pictures are related, because there is conflict between the activation of the lexical representations of both pictures that are competing for selection. In the current study, the expected behavioural and electrophysiological correlations between the interference conditions from the picture selection task and the interference conditions from the flanker task were not found, except for the French phonological-within cost condition in the behavioural data that correlated with the mixing costs. This illustrates that the smaller the degree of conflict experienced in the flanker task, the smaller the interference elicited in the phonological condition in the picture selection task. An explanation for why such a correlation was limited to the phonological condition and observed for the French version only cannot be accounted for. However, the mixing costs are predominantly where the effects of bilingualism should emerge considering that past research has attributed the bilingual advantage to more efficient conflict monitoring abilities with respect to engaging attentional control compared to monolinguals (Hilchey and Klein, 2011). It was also found that the absolute RTs from the picture selection task correlated with the overall RT measure of the flanker task, however these relations could be due to speed of processing. In retrospect, a baseline condition, where the target arrow is presented alone, would have circumvented this problem.

The role of executive control in resolving lexical conflict still remains an open question for several reasons. The first reason is that our sample size may have been too small for correlational analyses to be conducted. As Button et al. (2013) explain in their review paper, underpowered studies due to small sample sizes have a smaller likelihood of detecting true significant effects. This may also be the reason why sporadic correlations were observed for particular conditions (e.g, the N400 ERP amplitude of the English unrelated condition with the P3 ERP amplitude of the incongruent condition or the N400 amplitude difference of the English phonological-between condition with the P3 ERP amplitude difference of the flanker effect) and not for others. The second reason is that the flanker task may not have required enough effortful processing. Blumenfeld and Marian (2011) found a correlation between the degree of lexical inhibition in their negative-priming task and Stroop performance for bilinguals but not for monolinguals, which suggests a link between executive control and language processing. However, compared to the flanker task, the Stroop task is more cognitively demanding as it requires inhibition of an automatically primed word-recognition process. Perhaps with a larger sample size and a more cognitively demanding executive control task, correlations between lexical competition resolution and executive control would emerge.

The previous literature has indicated that on linguistic tasks, such as verbal fluency, vocabulary size is an important factor that influences performance. Correlations for category fluency revealed that the more words generated in French, the better their performance on the French picture selection task. Additionally, the French PPVT score correlated negatively with the semantic and unrelated condition on the French picture selection task. Such correlations were not found for the English picture selection task. Together, these correlations illustrate that there is a relation between vocabulary knowledge and performance on the picture selection task that is especially apparent in the weaker language. Prior research has shown that the level of L2 competence influences both the speed and accuracy of second language speech encoding (Declerck & Kormos, 2012) and second language reading (Carrell, 1991), consistent with our findings.

In conclusion, when a linguistic task involves conflict between lexical representations, bilinguals do not integrate information to the same extent as monolinguals. Therefore, bilinguals process and resolve lexical competition differently from monolinguals. The findings from the current study provide further insight into current theories on language processing in general, such that bilinguals are able to more efficiently manage conflict between lexical entries. Hence, not only do bilinguals outperform monolinguals on non-verbal tasks that involve conflict (see Bialystok, 2011 for a review), but also the present study extends the bilingual advantages to verbal tasks that involve conflict. These results are consistent with the functional imaging study by Abutalebi et al. (2012) that reported more efficient processing for bilinguals than monolinguals on both verbal and non-verbal tasks.

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Table 1

Mean English and French Background Statistics for the Words in Each Condition of the Picture Selection Task

Word Type	Word Frequency	Word Length	# of Phonemes	Orthographic Neighbourhood	Phonological Neighbourhood
English					
Target	24.16	5.30	3.92	5.78	12.27
Unrelated	27.79	5.25	4.18	4.13	8.76
Semantic	42.67	5.40	4.21	4.31	10.05
Phonological-Within	34.21	5.13	4.13	6.29	14.03
Phonological-Between	32.53	5.35	4.00	5.71	12.68
French					
Target	45.38	6.03	4.18	3.52	10.65
Unrelated	43.58	6.33	4.60	2.73	6.25
Semantic	25.39	5.68	4.15	3.73	9.13
Phonological-Within	49.32	6.75	4.54	3.38	9.59
Phonological-Between	53.41	6.90	4.67	3.05	6.89

Note. Word frequency statistics in English are based on the Kucera-Francis database and word frequency statistics in French are based on the Lexique 2 database.

Table 2

Bilingual Language Profile and LSBQ Results

Measure	English (n=21)	French (n=21)	Other Language (n=17)
Self-Rating			
Speaking	93.7 (12.8)	72.1 (17.5)	71.4 (25.7)
Understanding	96.6 (7.9)	92.1 (9.5)	87.0 (16.4)
Reading	93.9 (10.6)	89.3 (17.9)	35.9 (32.6)
Writing	91.7 (14.0)	67.9 (33.7)	26.1 (29.0)
Age of acquisition	5 (4)	4 (3)	4 (6)

Note. Standard deviations are in parentheses.

Table 3

Mean RTs and Accuracy Rates on the Picture Selection Task by Language

	English		French	
Condition	RT (ms)	Accuracy	RT (ms)	Accuracy
Unrelated	729 (64.1)	.99 (.02)	757 (100.5)	.98 (.03)
Semantic	928 (111.7)	.90 (.05)	920 (135.2)	.89 (.06)
Phonological-Within	748 (92.3)	.97 (.03)	780 (100.8)	.96 (.03)
Phonological-Between	729 (54.8)	.99 (.02)	772 (82.5)	.97 (.03)

Note. Standard deviations are in parentheses.

Table 4

Independent Samples t-tests Comparing English L1 Participants to French L1 Participants on the Picture Selection Task

Condition	MD	SED	95% CI LL	95% CI UL	*t*(19)	*p*	*d*
English							
Unrelated	14.4	36.4	-61.8	90.6	.40	.70	.18
Semantic	-34.9	63.2	-167.1	97.3	-.55	.59	.25
Phonological-Within	40.0	51.8	-68.4	148.5	.77	.45	.35
Phonological-Between	27.3	30.6	-36.8	91.4	.89	.38	.41
Semantic Cost	-49.6	41.8	-137.2	38.0	-1.19	.25	.55
Phonological-Within Cost	26.0	27.7	-31.9	83.9	.94	.36	.43
Phonological-Between Cost	12.4	22.4	-34.4	59.3	.56	.59	.26
French							
Unrelated	79.0	54.4	-34.8	192.8	1.45	.16	.67
Semantic	112.1	72.7	-40.0	264.3	1.54	.14	.71
Phonological-Within	100.1	52.7	-10.2	210.4	1.90	.07	.87
Phonological-Between	74.0	43.9	-17.8	165.8	1.69	.11	.78
Semantic Cost	33.1	49.7	-70.8	137.1	.67	.51	.31
Phonological-Within Cost	21.5	23.3	-27.3	70.3	.92	.37	.42
Phonological-Between Cost	-5.1	29.8	-67.5	57.3	-.17	.87	.08

Note. CI = confidence interval; LL = lower limit; MD = mean difference; SED = standard error of difference; UL = upper limit.

Table 5

Independent Samples t-tests Comparing Participants Fluent in English and French Only to Participants Fluent in a Third Language on the Picture Selection Task

Condition	MD	SED	95% CI LL	95% CI UL	*t*(19)	*p*	*d*
English							
Unrelated	-16.2	40.9	-101.7	69.3	-.40	.70	.18
Semantic	-23.2	71.3	-172.3	126.0	-.33	.75	.15
Phonological-Within	-9.3	59.0	-132.8	114.2	-.16	.88	.07
Phonological-Between	-18.9	62.0	-270.3	232.5	-.31	.79	.14
Semantic Cost	-7.0	48.6	-108.8	94.8	-.14	.89	.06
Phonological-Within Cost	6.3	31.7	-60.1	72.7	.20	.84	.09
Phonological-Between Cost	-3.0	25.3	-56.0	50.0	-.12	.91	.06
French							
Unrelated	10.9	64.3	-123.5	145.4	.17	.87	.08
Semantic	-54.3	85.6	-233.5	124.9	-.63	.53	.29
Phonological-Within	-20.8	64.3	-155.4	113.9	-.32	.75	.15
Phonological-Between	14.6	52.7	-95.6	124.9	.28	.78	.13
Semantic Cost	-65.2	54.4	-179.0	48.5	-1.20	.25	.55
Phonological-Within Cost	-31.8	25.7	-85.6	22.0	-1.24	.23	.57
Phonological-Between Cost	3.4	33.5	-66.7	73.4	.10	.92	.05

Note. CI = confidence interval; LL = lower limit; MD = mean difference; SED = standard error of difference; UL = upper limit.

Table 6

Mean RTs and Accuracy Rates on the Flanker Task by Trial Type

Conditions	RT (ms)	Accuracy
Congruent Pure	417 (46.7)	.98 (.02)
Congruent Mixed	457 (66.7)	.99 (.02)
Incongruent Mixed	506 (63.0)	.94 (.05)

Note. Standard deviations are in parentheses.

Table 7

Mean Score for the Verbal Fluency Tasks by Language

Task	English	French
Letter Fluency	11.3 (2.6)	8.1 (2.5)
Category Fluency	17.3 (4.7)	12.8 (3.4)

Note. Standard deviations are in parentheses.

Table 8

Correlations between the Picture Selection Task RTs, the Flanker Task RTs, Verbal Fluency Scores, and PPVT Score

Condition	Flanker	Incongruent Condition	Letter Fluency	Category Fluency	PPVT
English					
Unrelated	.65** [0.3, 0.8]	.56** [0.2, 0.8]	-.26 [-0.5, 0.1]	-.05 [-0.5, 0.4]	-.27 [-0.6, 0.2]
Semantic	.69*** [0.3, 0.9]	.63** [0.2, 0.9]	-.18 [-0.6, 0.2]	.14 [-0.3, 0.6]	-.22 [-0.6, 0.2]
Phonological-Within	.67*** [0.5, 0.9]	.58** [0.3, 0.9]	-.14 [-0.5, 0.2]	-.06 [-0.5, 0.4]	-.32 [-0.6, 0.2]
Phonological-Between	.74*** [0.5, 0.9]	.64** [0.4, 0.8]	-.02 [-0.4, 0.4]	.14 [-0.3, 0.5]	-.29 [-0.6, 0.2]
French					
Unrelated	.49* [0.2, 0.7]	.37 [0.0, 0.7]	-.21 [-0.7, 0.3]	-.53* [-0.8, -0.2]	-.44* [-0.8, -0.0]
Semantic	.46* [0.2, 0.8]	.36 [0.0, 0.7]	-.22 [-0.8, 0.3]	-.53* [-0.8, 0.2]	-.62** [-0.8, -0.4]
Phonological-Within	.62** [0.3, 0.8]	.52* [0.2, 0.8]	-.24 [-0.7, 0.2]	-.50* [-0.8, -0.2]	-.43 [-0.8, -0.0]
Phonological-Between	.65*** [0.4, 0.8]	.56** [0.3, 0.8]	-.43 [-0.8, -0.1]	-.64** [-0.9, -0.3]	-.35 [-0.7, -0.0]

Note. $*p < .05$, $**p < .01$, $***p < .001$. 95% confidence intervals, lower limit and upper limit, are shown in the square brackets.

Table 9

Correlations between the Picture Selection Task Cost RTs and Flanker task Mixing Costs and Flanker Effect RTs

Language	Cost Condition	Mixing Costs	Flanker Effect
English			
	Semantic	.34 [-0.2, 0.7]	-.08 [-0.6, 0.3]
	Phonological-Within	.31 [-0.1, 0.6]	-.06 [-0.6, 0.4]
	Phonological-Between	-.18 [-0.7, 0.3]	.18 [-0.2, 0.6]
French			
	Semantic	.13 [-0.4, 0.6]	-.08 [-0.5, 0.4]
	Phonological-Within	.53* [0.2, 0.8]	-.06 [-0.5, 0.4]
	Phonological-Between	.23 [-0.2, 0.6]	.18 [-0.2, 0.6]

Note. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$. 95% confidence intervals, lower limit and upper limit, are shown in the square brackets.

Table 10

Picture Selection Task Brain-Behaviour Correlations: RTs and N400 Mean Amplitudes

	Reaction Times	
ERP amplitudes (N400)	English	French
Unrelated	-.10 [-0.5, 0.3]	-.19 [-0.7, 0.5]
Semantic	-.27 [-0.7, 0.2]	-.23 [-0.7, 0.2]
Phonological-Within	-.31 [-0.6, 0.0]	-.05 [-0.4, 0.3]
Phonological-Between	-.15 [-0.5, 0.2]	-.19 [-0.5, 0.2]

Note. **p* < .05, ***p* < .01, ****p* < .001. 95% confidence intervals, lower limit and upper limit, are shown in the square brackets.

Table 11

Picture Selection Task Brain-Behaviour Correlations: Cost RTs and N400 Mean Amplitude Differences

	Cost Reaction Times	
ERP amplitudes differences (N400)	English	French
Semantic	.12 [-0.3, 0.5]	-.18 [-0.5, 0.2]
Phonological-Within	-.13 [-0.5, 0.2]	-.04 [-0.4, 0.4]
Phonological-Between	.15 [-0.3, 0.5]	-.29 [-0.6, 0.2]

Note. **p* < .05, ***p* < .01, ****p* < .001. 95% confidence intervals, lower limit and upper limit, are shown in the square brackets.

Table 12

Flanker Task Brain-Behaviour Correlations: RTs and P3/N2 Mean Amplitudes

		Reaction Time	
ERP component	Condition	Congruent Mixed	Incongruent Mixed
N2			
	Congruent Mixed	.40 [-0.7, 1.0]	
	Incongruent Mixed		-.09 [-0.5, 0.3]
P3			
	Incongruent Mixed		-.46* [-0.7, -0.2]

Note. **p* < .05, ***p* < .01, ****p* < .001. 95% confidence intervals, lower limit and upper limit, are shown in the square brackets.

Table 13

Flanker Task Brain-Behaviour Correlations: Flanker Effect/Mixing Cost RTs and P3/N2 Mean Amplitude Differences

		Cost RTs	
ERP component	Cost Condition	Flanker Effect	Mixing Costs
N2			
	Flanker Effect	-.26 [-0.6, 0.2]	
	Mixing Costs		-.04 [-0.3, 0.2]
P3			
	Flanker Effect	-.22 [-0.0, 0.6]	

Note. $*p < .05$, $**p < .01$, $***p < .001$. 95% confidence intervals, lower limit and upper limit, are shown in the square brackets.

Table 14

Correlations between Mean Amplitudes across ERP Tasks

Picture Selection	Flanker Task		
N400	N2		P3
Conditions	CM	IM	IM
English			
Unrelated	.41 [-0.1, 0.7]	.26 [-0.2, 0.6]	.45* [0.1, 0.7]
Semantic	.24 [-0.3, 0.5]	-.02 [-0.4, 0.4]	.15 [-0.2, 0.5]
Phonological-Within	.20 [-0.1, 0.4]	.03 [-0.3, 0.4]	.30 [-0.5, 0.7]
Phonological-Between	.32 [-0.1, 0.6]	-.05 [-0.2, 0.5]	.33 [0.1, 0.6]
French			
Unrelated	.06 [-0.3, 0.4]	.10 [-0.3, 0.5]	.28 [-0.1, 0.6]
Semantic	.13 [-0.2, 0.5]	.10 [-0.4, 0.5]	.21 [-0.2, 0.6]
Phonological-Within	.18 [-0.2, 0.5]	.05 [-0.4, 0.5]	.34 [-0.2, 0.7]
Phonological-Between	.11 [-0.2, 0.4]	.06 [-0.3, 0.5]	.35 [-0.1, 0.7]

Note. *$p < .05$, **$p < .01$, ***$p < .001$; CP = congruent pure condition; CM = congruent mixed condition; IM = incongruent mixed condition. 95% confidence intervals, lower limit and upper limit, are shown in the square brackets.

Table 15

Correlations between Mean Amplitude Differences across ERP Tasks

	Picture Selection Task	Flanker Task		
	N400	N2		P3
Language	Conditions	Mixing Costs	Flanker Effect	Flanker Effect
English				
	Semantic	.11 [-0.5, 0.6]	-.27 [-0.7, 0.6]	-.32 [-0.7, 0.5]
	Phonological-Within	-.01 [-0.3, 0.3]	-.10 [-0.5, 0.3]	-.10 [-0.5, 0.3]
	Phonological-Between	-.36 [-0.7, 0.2]	-.14 [-0.5, 0.3]	-.44* [-0.8, 0.2]
French				
	Semantic	.24 [0.0, 0.5]	-.05 [-0.5, 0.3]	-.07 [-0.4, 0.3]
	Phonological-Within	.12 [-0.2, 0.4]	-.18 [-0.5, 0.2]	.30 [-0.1, 0.6]
	Phonological-Between	.10 [-0.3, 0.4]	-.16 [-0.6, 0.3]	.14 [-0.4, 0.6]

Note. **p* < .05, ***p* < .01, ****p* < .001. 95% confidence intervals, lower limit and upper limit, are shown in the square brackets.

Table 16

Reaction Times and Average Ratings for the Semantic Pairs High and Low in Visual Similarity

	Degree of Visual Similarity			
	Low		High	
Language	Semantic RTs	Mean Ratings	Semantic RTs	Mean Ratings
English	861 (80.7)	1.93 (.39)	1085 (200.6)	3.62 (.46)
French	881 (246.0)	1.65 (.71)	1036 (200.3)	3.22 (.71)

Note. Standard deviations are in parentheses.

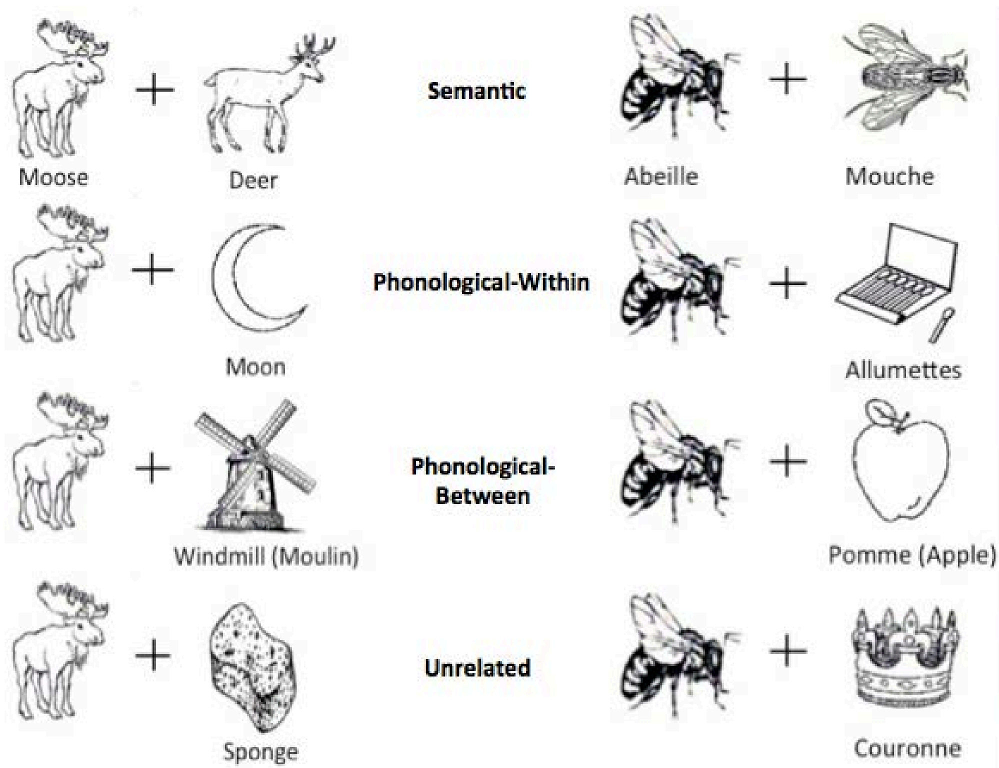

Figure 1. An example of an English set (left) and French set (right) from the picture selection task.

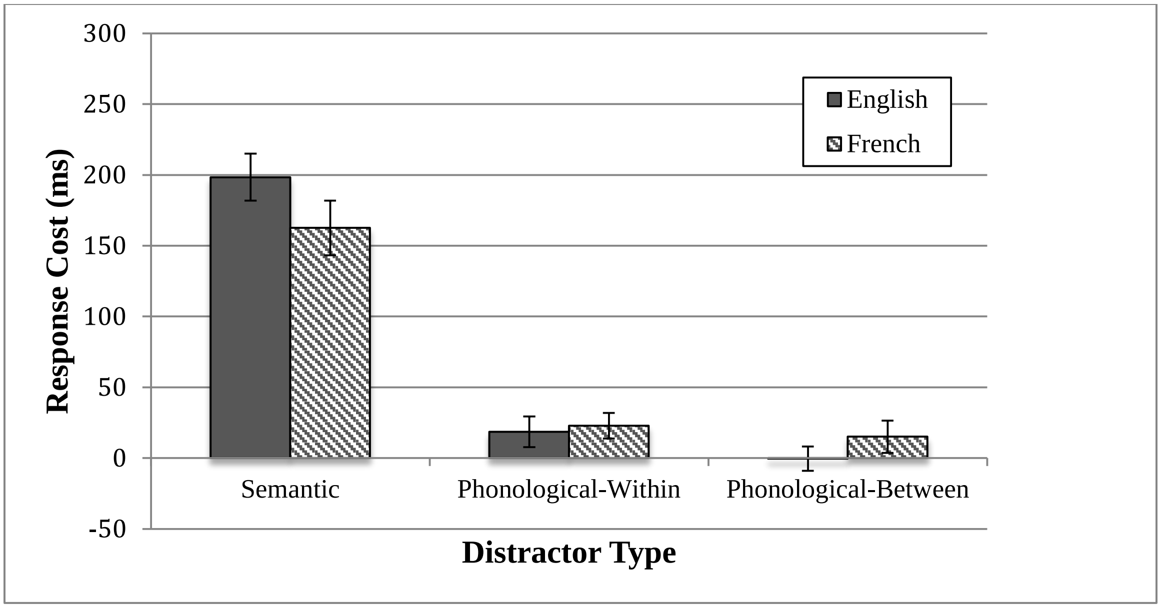

Figure 2. Mean reaction time cost and standard error bars as a function of distractor type and language on the picture selection task.

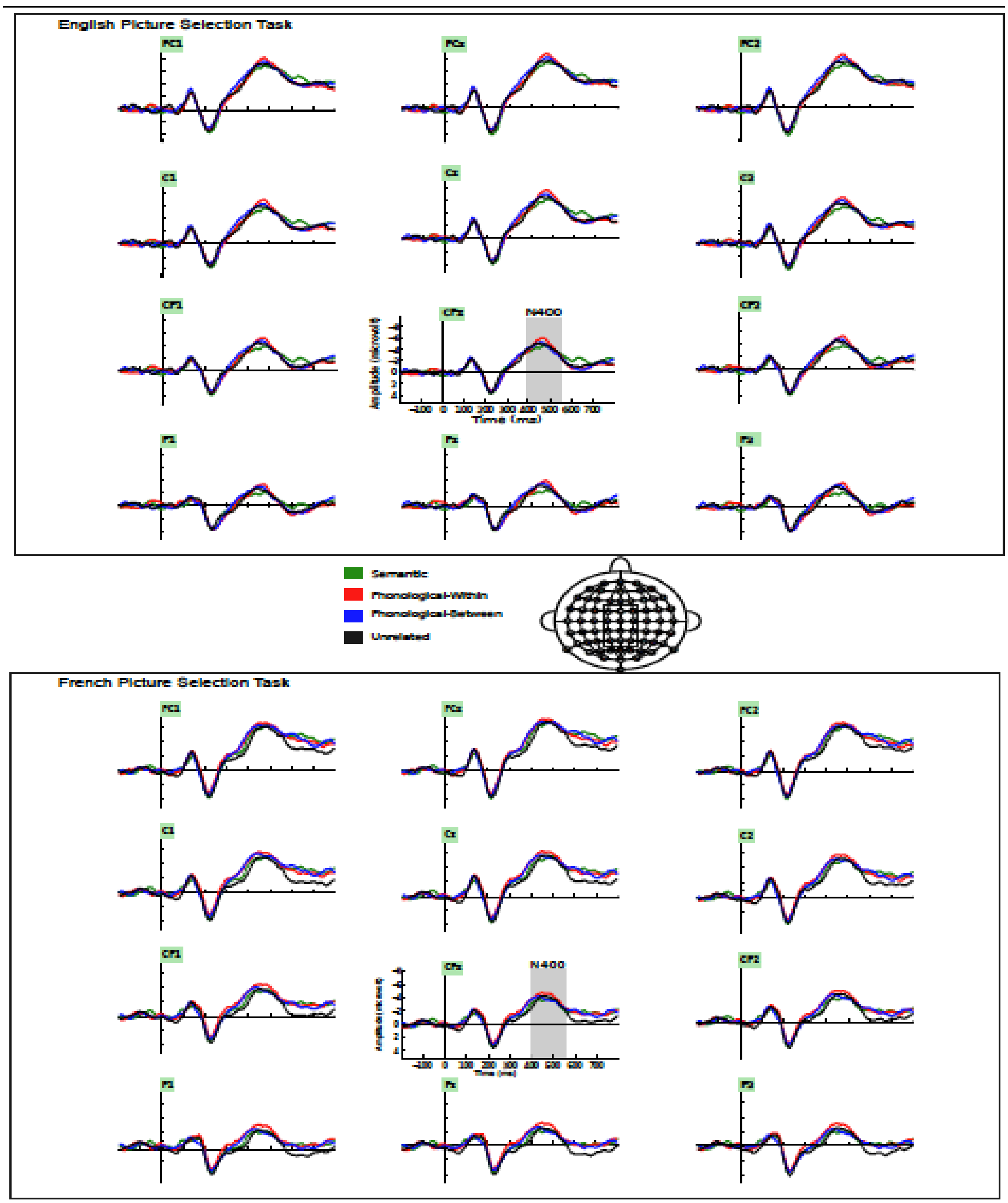

Figure 3. Grand average ERPs for all distractors types in the English (top) and French (bottom) picture selection task. The grey shaded area represents the time window for the N400.

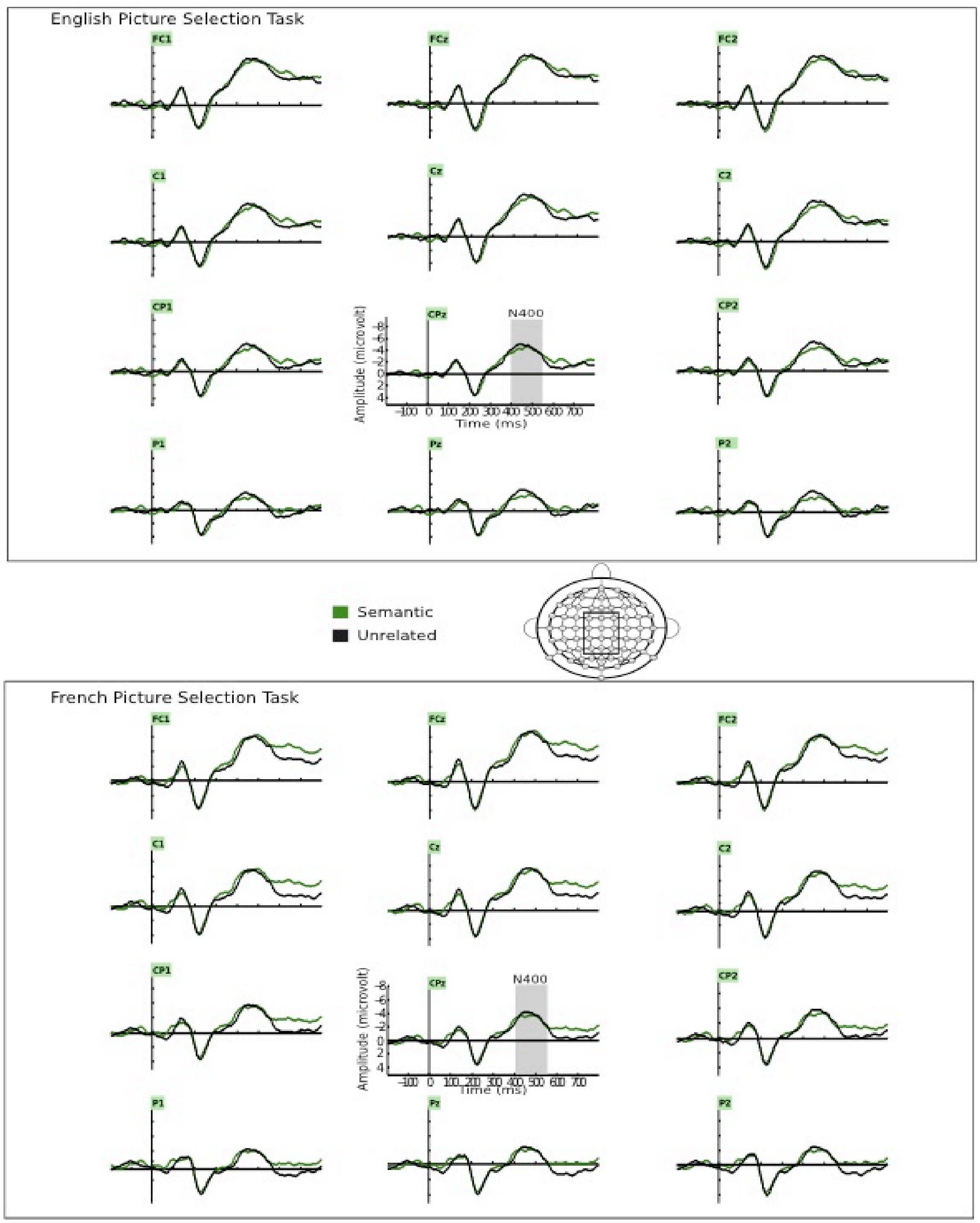

Figure 4. Grand average ERPs for the semantic and unrelated distractor in the English (top) and French (bottom) picture selection task. The grey shaded area represents the time window for the N400.

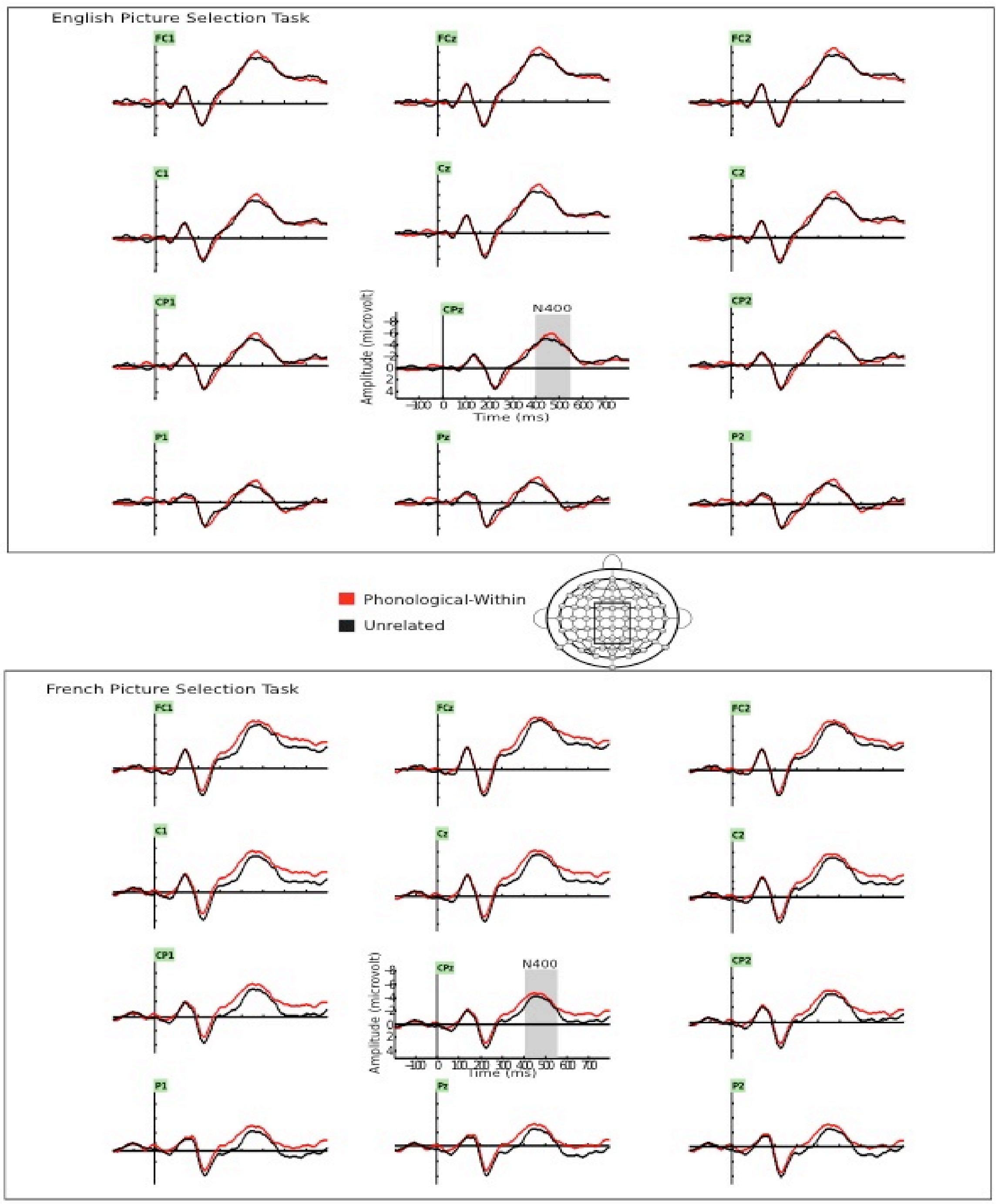

Figure 5. Grand average ERPs for the phonological-within and unrelated distractors in the English (top) and French (bottom) picture selection task. The grey shaded area represents the time window for the N400.

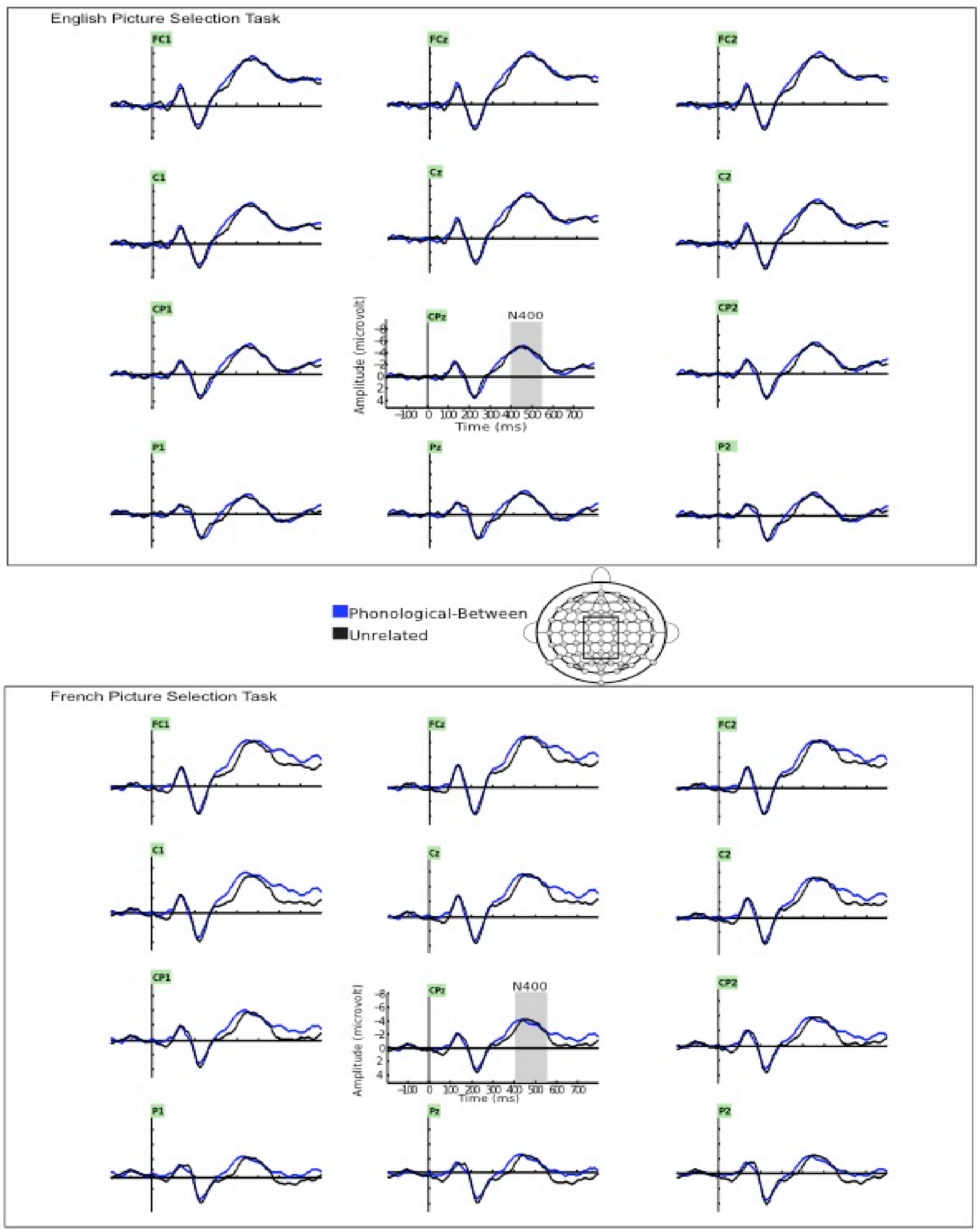

Figure 6. Grand average ERPs for the phonological-between and unrelated distractor in English (top) and French (bottom) picture selection task. The grey shaded area represents the time window for the N400.

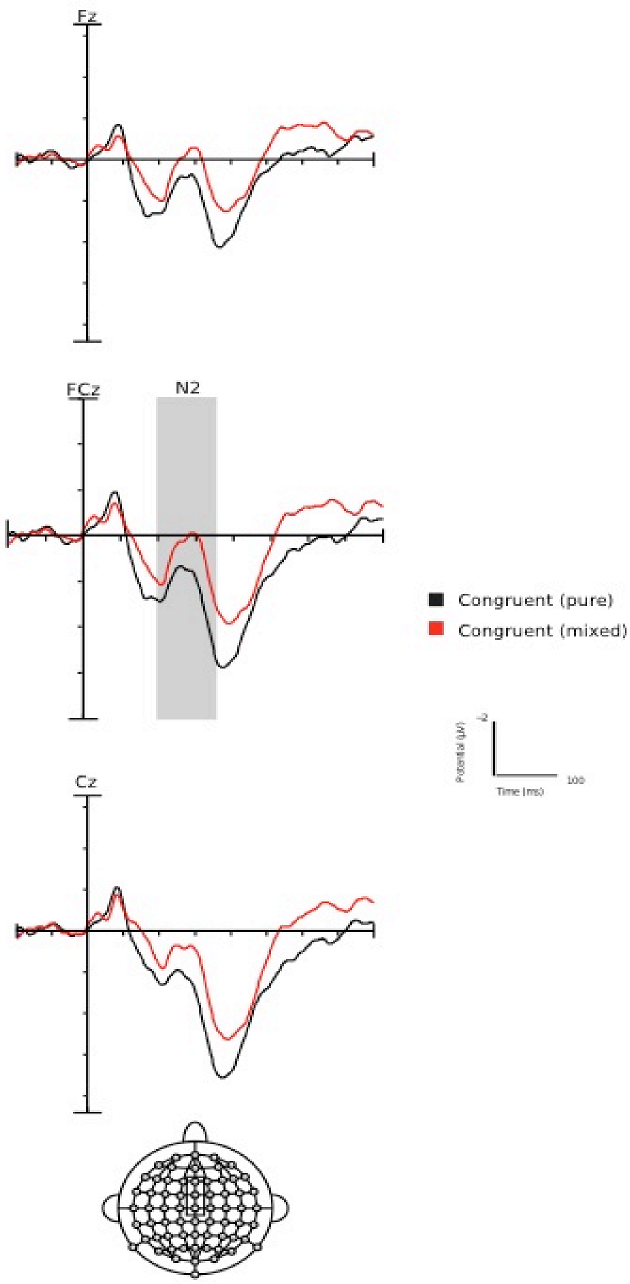

Figure 7. Grand average ERPs of the block effect (congruent pure vs. congruent mixed) for electrodes Fz, FCz, and Cz for the N2 component. The grey shaded area represents the time window for the N2 component.

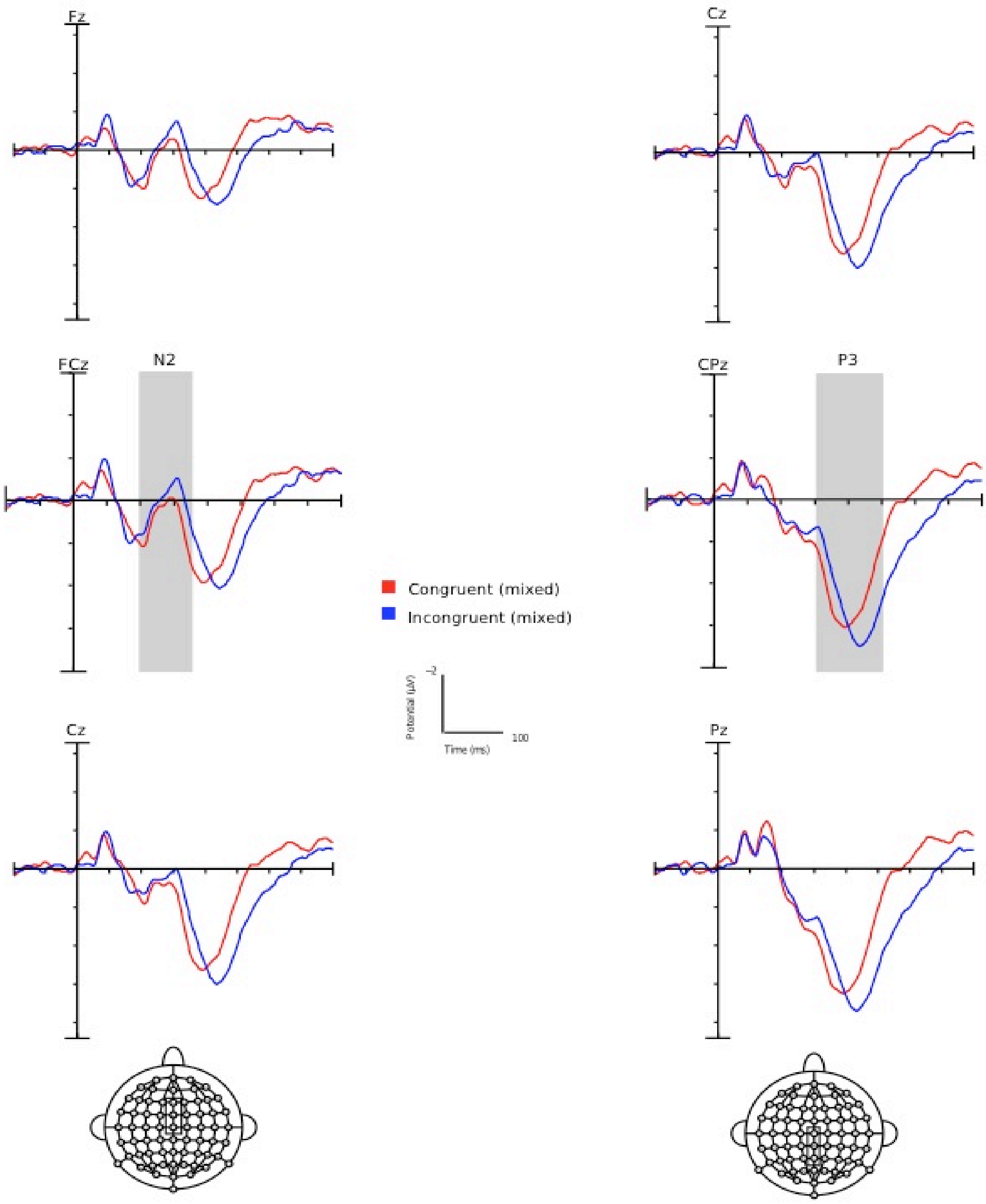

Figure 8. Grand average ERPs for the congruency effect (congruent mixed vs. incongruent mixed) for electrodes Fz, FCz, and Cz for the N2 component (left column) and electrodes Cz, CPz, and Pz for the P3 component (right column). The grey shaded area represents the time window for the N2 and P3 components.

Appendix A: The Informed Consent

INFORMED CONSENT
French-English Bilinguals Picture Selection Study

Sponsor: York University
This research has been approved by the Human Participants Review Subcommittee (HPRC) of York University for compliance with York University Senate Ethics policy.

Purpose of the Study
The purpose of the study is to better understand the effect of language on the ability to resolve sources of linguistic conflict in everyday speech. We will study adults from the York University URPP. Participants are selected based on their history of active use of another language in addition to English.

What You will be Asked to Do in the Study
You will be asked to complete some paper-based and computer-based cognitive tasks, for example:

- Answer some questions about your experience learning and speaking English and a second language.
- Generate words based on certain rules.
- Select a picture on a computer screen based on an auditory cue.
- Make left or right judgments according to a central stimulus.

During some of these tasks, we will use an electroencephalogram system (EEG) to record your brain activity. This is a non-invasive technique. This system is used frequently in research and with participants as young as 5 year old.

We will provide you with clear instructions and examples at the beginning of each task so that you will know what to do. When using the computer, you will give your answers by either clicking a mouse or the spacebar. If you do not know how to use a mouse, we will show you how to use one. We will provide you with breaks throughout the testing time if you wish to take them, and we will answer any questions that you may have. There are two sessions. Each session will take approximately 75 minutes to complete. You will receive course credit for the time you spent with the researcher.

Voluntary Participation
Participation in this study is completely voluntary. The decision to participate is entirely up to you.

Risks and Discomforts
We do not expect the study to cause any risks or discomforts for you. However, if you feel uncomfortable or become tired, you can take a break whenever you want.

Withdrawal from Study: You can stop participating in the study any time you want, for any reason you want. If you decide to withdraw, you do not need to give a reason, and it will not prejudice your future relations with me, with this university, or any part of this university. If you decide to stop participating for any reason, you will still be eligible to receive the promised pay (URPP credits) for agreeing to be in the project. Should you withdraw from the study all of your data generated will be destroyed.

Confidentiality
The information (data) we get from you during the study will be kept confidential. Your name will never be used in connection with any of the data we collect. Your signature below indicates that you are willing for the *information* we got from you to be used in an article or lecture as long as your name is not revealed. Your data will be safely stored in a locked file cabinet and only my supervisor and I will have access to this information. Your confidentiality will be maintained to the extent allowed by law.

Benefits
You will not receive direct benefit from being in this study. However, your participation will facilitate our understanding the role of language on various cognitive processes involved in conflict resolution.

Questions
If you have any questions about the research in general or about your role in the study, please feel free to contact me at ashc88@yorku.ca or my supervisor, Dr. Ellen Bialystok, either by phone at (416) 736-2100 x 66109 or by e-mail (ellenb@yorku.ca).

Ashley Chung-Fat-Yim, BSc.
MA Candidate

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Legal Rights and Signatures
You will receive a copy of this informed consent. You are not waiving any of your legal rights by signing this form. Your signature below indicates that you agree to participate in this study.

This research has been reviewed by the Human Participants in Research Committee, York University's Ethics Review Board and approved the protocol for compliance with Senate ethics policy. If you have any questions about this process, or about your rights as a participant in the study, please contact the Manager of Research Ethics for York University at the Office of Research Ethics, 309 York Lanes, York University (telephone 416-736-5914).

Name of Participant (Print): _________________________ Birth date: ___________________

Signature of Participant: ___________________________ Today's Date: ________________

Signature of Experimenter: _________________________ Today's Date: ________________

Appendix B: The Language and Social Background Questionnaire (LSBQ)

Cognition and Development Lab
Ellen Bialystok Ph.D, Principal Investigator
Department of Psychology, York University

<u>Language & Social Background Questionnaire</u>

1. Today's date (D/M/Y):_______________ 4.Occupation/UniversityMajor:__________

2. Sex: M F 5. Date of Birth (D/M/Y):______________

3. Handedness: L R

6. What is the highest year of school you have completed?________________________

7. What is the highest degree you have earned?_________________________________

8. On average, how many hours do you use a computer per week?__________________

9. On average, how many hours do you play video/computer games per week? ________

10. Do you have hearing problems? Yes No

    If Yes, do you wear a hearing aid? Yes No

11. Do you have vision problems? Yes No

    If Yes, do you wear glasses/contacts? Yes No

    Is your vision corrected to 20/20 with glasses/contacts? Yes No

12. Are you colour blind? Yes No

    If Yes, what type? _______________________

13. Do you have any known neurological impairments? Yes No

    Have you ever had a head injury? Yes No

    Are you currently taking any psychoactive medications? Yes No

Please indicate the highest level of education for each parent:

14. **Mother**	15. **Father**
1._____No high school diploma	1. _____No high school diploma
2. _____High school graduate	2. _____High school graduate
3. _____Some college or college diploma	3. ____Some college or college diploma
4. _____Bachelor's Degree	4. _____Bachelor's Degree
5. _____Graduate or professional degree	5. _____Graduate or professional degree
Native language: ___________________	Native language: _______________
Second language: ___________________	Second language: ________________

16. Were you born in Canada? Yes No

If No, where were you born? ____________________________________

When did you move to Canada? ____________________________

Have you ever lived in a place where English is not the dominant communicating language? Yes No

If Yes, where & for how long?					
1	_____________________	From:	___________	To:	___________
2	_____________________	From:	___________	To:	___________
3	_____________________	From:	___________	To:	___________

17. ***Language Background***

List all the languages and dialects you can speak including English, *in order of fluency*:

Language	**Where did you learn it? (Home, School, Community)**	**Where do you use it? (Home, School, Friends, Travel, Other)**	**At what age did you learn it?**
1.			
2.			

3.			
4.			
5.			

Do you have any knowledge of another language, even though you are not fluent?

Yes No

If Yes, please explain____

Did you study any other languages during high school? Yes No

If Yes, which language and for how many years?________________________

On each of the following scales, indicate the proportion of use for English and your other language in **daily life**. On one end, 0 indicates that the activity in that environment is carried out in ALL ENGLISH. On the other end, 100 indicates that only the other language(s) is used. You can mark anywhere on the scale, so please be as precise as possible.

All English No English

0 25 50 75 100

1. Language spoken to family members
2. Language spoken to friends
3. Language for watching watched TV/video
4. Language for reading books/magazines, etc
5. Language written (e.g. shopping list, notes)
6. Language used in the community and cultural activities.

Relative to a native speaker's performance, rate your proficiency level in a scale of 0 – 100 for the following activities conducted in English and your other language.

English

No Proficiency — Native-like
0 25 50 75 100

Speaking

Understanding (Comprehension)

Reading

Writing

Other Language: ______________________ (please indicate)

No Proficiency — Native-like
0 25 50 75 100

Speaking

Understanding (Comprehension)

Reading

Writing

Global self-assessment:

Overall, how would you describe your level of bilingualism?

Not bilingual   Non-fluent bilingual   Fluent bilingual

1   2   3   4   5

1 – speak predominantly one language
- – only know a few vocabulary in the other language.

2 – weak bilingual
- – know enough to carry out some conversation to a very limited extent (use key words with not much grammar)
- – need to listen to sentences more than once before understanding.

3 – unbalanced bilingual
- – able to carry out basic conversation with minor grammatical errors
- – without the other speaker repeating the sentence
- – has difficulty producing a fluent conversation.

4 – practical bilingual
- – can carry out conversation fluently
- – does not use the second language everyday

5 – fluent bilingual
- – able to converse fluently and actively use two languages everyday
- – lived abroad in a community that has English as the dominant language

Experimenter's judgment: __________

Appendix C: The French Language Experience Questionnaire (FLEQ)

French Language Experience Questionnaire

1.) Have you ever travelled to/lived in any French speaking countries or French speaking communities? YES__ NO__

If YES, where and for how long?
____
____

2.) Have you ever been in a foreign-exchange study program? YES__ NO__

If YES, where and for how long?
____
____

3.)School Experience
Put **one** 'X' in the column for each grade level to indicate what kind of schooling you had:

	K	1	2	3	4	5	6	7	8	9	10	11	12	U1	U2	U3	U4
English school (no French course)																	
English school (a French course (CORE)																	
English school (French Immersion)																	
French school (no English course)																	
French school (an English course)																	
Other																	

4.) If you are no longer taking French classes, why did you stop?
____
____

French (if not already completed)

No Proficiency 0 — Native-like 100

Speaking

Understanding

Reading

Writing

Immersion Students

1.) Where did you go to school? (ie. school board, city)

____

2.) On average, what percent of your day was spent speaking French?

Elementary School____% High School____%

3.) If you attended a high school with French immersion courses, what classes did you take in French?

Grade 9	Grade 10	Grade 11	Grade 12

4.) How often would you speak French at school, while outside the classroom?

Never 1 2 3 4 5 6 7 8 9 10
Always

5.) How would you rate the quality of your Immersion education?

Poor quality 1 2 3 4 5 6 7 8 9 10
High quality

6.) If you are no longer speaking French on a daily basis, how long has it been since you have used French on a daily basis?

____

Appendix D: List of Pictures Used in the English Picture Selection Task

Target	Phonological -Within	Phonological-Between (Translation)	Semantic	Unrelated
Apple	Ant	Spider (Araignée)	Pear	Drum
Arm	Arch	Tree (Arbre)	Leg	Skunk
Axe	Ashtray	Matches (Allumette)	Saw	Mouse
Backpack	Battery	Ring (Bague)	Purse	Flower
Barn	Barbell	Whale (Baleine)	House	Magnet
Barrel	Bear	Cradle (Berceau)	Crate	Star
Beaker	Beach	Cookie (Biscuit)	Funnel	Knife
Bell	Belt	Donut (Beigne)	Whistle	Cherry
Boot	Book	Candle (Bougie)	Shoe	Cow
Broom	Brain	Wheelbarrow	Vacuum	Cricket
Cabbage	Cabinet	Beaver (Castor)	Eggplant	Sheep
Car	Cat	Duck (Canard)	Bus	Paddle
Caterpillar	Castle	Gift (Cadeau)	Worm	Window
Celery	Centipede	Kite (Cerf-Volant)	Lettuce	Glove
Claw	Clip	Keyboard (Clavier)	Hoof	Turtle
Clown	Cloud	Key (Clé)	Joker	Sun
Coat	Corn	Heart (Coeur)	Jacket	Peacock
Cockroach	Coffin	Necklace (Collier)	Beetle	Skirt
Comb	Computer	Pig (Cochon)	Brush	Snake
Fly	Flag	Arrow (Flèche)	Bee	Clock
Fox	Faucet	Oven (Four)	Wolf	Pumpkin
Fridge	Frog	Strawberry (Fraise)	Microwave	Ladybug
Gavel	Gazebo	Cake (Gâteau)	Hammer	Owl
Ladder	Lamb	Rabbit (Lapin)	Stairs	Chimney
Lip	Lid	Bed (Lit)	Nose	Sock
Lobster	Lock	Tongue (Langue)	Shrimp	Ear
Moose	Moon	Windmill (Moulin)	Deer	Sponge
Moth	Money	Watch (Montre)	Butterfly	Bread
Pacifier	Pan	Umbrella (Parapluie)	Rattle	Crown
Pepper	Pencil	Shovel (Pelle)	Mushroom	Flamingo
Pineapple	Pillow	Straw (Paille)	Coconut	Bucket
Pliers	Plane	Feather (Plume)	Wrench	Horse
Rain	Railing	Grape (Raisin)	Snow	Squirrel
Rooster	Rope	Wheel (Roue)	Chicken	Truck
Seal	Seed	Lemon (Citron)	Walrus	Tie
Shark	Shelf	Hat (Chapeau)	Eel	Peanut
Ship	Shield	Dog (Chien)	Boat	Desk
Shirt	Shell	Hair (Cheveux)	Dress	Fish
Starfish	Stool	Pen (Stylo)	Octopus	Basket
Toe	Toaster	Bull (Taureau)	Finger	Plug

Appendix E: List of Pictures Used in the French Picture Selection Task

Target	Phonological-Within	Phonological-Between (Translation)	Semantic	Unrelated
Abeille	Allumette	Pomme (Apple)	Mouche	Couronne
Agrafeuse	Araignée	Cendrier (Ashtray)	Perforatrice	Coffre
Aigle	Aiguille	Œuf (Egg)	Hibou	Cravate
Baleine	Balançoire	Panier (Basket)	Requin	Pupitre
Bateau	Bague	Chauve-souris (Bat)	Navire	Griffe
Berceau	Beigne	Ceinture (Belt)	Landau	Moufette
Bouclier	Bouche	Taureau (Bull)	Épée	Éponge
Canard	Camion	Bougie (Candle)	Oie	Lunette
Castor	Casque	Château (Castle)	Loutre	Pluie
Cerf	Cerveau	Millepattes (Centipede)	Orignal	Parapluie
Chaise	Chameau	Ombre (Shadow)	Tabouret	Poire
Champignon	Chapeau	Crevette (Shrimp)	Pois	Sapin
Chemise	Chenille	Coquillage (Shell)	Robe	Oreille
Cheval	Chandail	Étagère (Shelf)	Âne	Marteau
Chien	Chou	Rasoir (Shaver)	Loup	Tambour
Ciseaux	Citrouille	Phoque (Seal)	Règle	Plage
Clé	Clavier	Trèfle (Clover)	Serrure	Jupe
Cloche	Clôture	Nuage (Cloud)	Sifflet	Oiseau
Clou	Climatiseur	Horloge (Clock)	Vis	Sauterelle
Coccinelle	Collier	Maïs (Corn)	Scarabée	Avion
Coco	Colombe	Manteau (Coat)	Ananas	Écureuil
Coeur	Colle	Tirebouchon (Corkscrew)	Poumon	Fenêtre
Concombre	Confiture	Pièce (Coin)	Laitue	Serpent
Dauphin	Doigt	Porte (Door)	Poisson	Poupée
Fleur	Flèche	Drapeau (Flag)	Arbre	Poulet
Fourchette	Fourmi	Pied (Foot)	Cuillère	Papillon
Fraise	Fromage	Grenouille (Frog)	Cerise	Ours
Gâteau	Gant	Poubelle (Garbage)	Tarte	Plume
Lapin	Larmes	Échelle (Ladder)	Raton-laveur	Étoile
Lit	Livre	Feuille (Leaf)	Canapé	Couteau
Maison	Main	Aimant (Magnet)	Grange	Cadeau
Mouton	Moulin	Lune (Moon)	Agneau	Église
Nez	Neige	Genou (Knee)	Oeil	Voiture
Peigne	Pelle	Stylo (Pen)	Brosse	Montre
Roue	Rouge a lèvres	Coq (Rooster)	Pneu	Selle
Seau	Sorcière	Chaussette (Sock)	Bocal	Renard
Soulier	Souris	Valise (Suitcase)	Botte	Tondeuse
Tasse	Tapis	Robinet (Tap)	Verre	Singe
Tortue	Tonneau	Langue (Tongue)	Homard	Paille
Vache	Vague	Aspirateur (Vacuum)	Cochon	Jambe

Appendix F: The Debriefing Form

Debriefing Form: Picture Selection Study

Study title: French-English Bilingual Picture Selection Study

Research's name: Ashley Chung-Fat-Yim

Supervisor's name: Dr. Ellen Bialystok

Purpose of the Research:

An unanswered question for bilinguals is what factors contribute towards resolving lexical competition within a single language and across languages. Lexical competition arises from lexical entries that share phonological and semantic characteristics. Previous studies have demonstrated electrophysiological differences between monolinguals and bilinguals when resolving within-language lexical competition (Friesen, Rakoczy, & Bialystok, 2011) but it is unclear how these differences arise. This study is important as it will expand our current knowledge on the nature of bilingual language processing, particularly in linguistic tasks that require conflict resolution.

First you filled out a questionnaire that examined your language use patterns and level of bilingualism. You were then asked to identify pictures and generate words to determine your English and French vocabulary knowledge. Afterwards, you were given a Picture Selection Task in French and/or in English in order to assess your resolution processes when presented with related versus unrelated pictures. Finally, you were asked to perform a computerized Flanker task to assess your executive control abilities.

If you have any questions, feel free to contact me at ashc88@yorku.ca. You can also contact my supervisor, Dr. Ellen Bialystok, at ellenb@yorku.ca. If you have any concerns about this study, please contact the departmental ethics committee.

Thank you for participating!