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# Lexical selection differences between monolingual and bilingual listeners ☆

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ABSTRACT

Three studies are reported investigating how monolinguals and bilinguals resolve within-language competition when listening to isolated words. Participants saw two pictures that were semantically-related, phonologically-related, or unrelated and heard a word naming one of them while event-related potentials were recorded. In Studies 1 and 2, the pictures and auditory cue were presented simultaneously and the related conditions produced interference for both groups. Monolinguals showed reduced N400s to the semantically-related pairs but there was no modulation in this component by bilinguals. Study 3 inserted an interval between picture and word onset. For picture onset, both groups exhibited reduced N400s to semantically-related pictures; for word onset, both groups showed larger N400s to phonologically-related pictures. Overall, bilinguals showed less integration of related items in simultaneous (but not sequential) presentation, presumably because of interference from the activated non-English language. Thus, simple lexical selection for bilinguals includes more conflict than it does for monolinguals.



## 1. Introduction

In the bilingualism literature, language processing and executive control (EC) are usually investigated separately. For the former, bilinguals typically exhibit lower levels of language proficiency and slower linguistic processing than monolinguals (review in Kroll, Dussias, Bogulski, & Valdes Kroff, 2012); for the latter, bilinguals often demonstrate faster or more efficient processing on non-verbal cognitive control tasks than monolinguals (review in Bialystok & Craik, 2010). Explanations for observed bilingual processing advantages in non-verbal tasks have focused on descriptions of how bilinguals manage their two languages, essentially combining these two areas of investigation. The key point is that both languages of a bilingual are jointly activated, so bilinguals must select between the target and distractor languages and ignore alternatives from the non-target language. This constant need to resolve competition between jointly-activated languages explains both the difficulty in linguistic processing and the enhancement of domain-general control (Bialystok, Craik, Green, & Gollan, 2009). Yet, monolinguals are also subject to selection pressures from within-language alternatives (e.g., cup vs. mug). If this selection process is similar for monolinguals within a language as it is for bilinguals selecting across languages, then such linguistic selection is unlikely to be responsible for the bilingual advantages in domain-general control because speakers in both groups should benefit equally. The present study used event-related potentials (ERPs) to compare these lexical selection processes for monolinguals and bilinguals within a single language. The hypothesis is that cross-language selection adds unique processing demands for bilinguals and results in less within-language integration on related stimuli even within a single language. Failure to integrate related within-language stimuli would reflect greater conflict and the need to recruit more EC. Thus, evidence for different processes underlying lexical selection in a single language will clarify the putative mechanism by which bilingualism leads to enhanced executive control and link the two lines of research into a more coherent explanation.

The notion motivating the present study is that the continual involvement of executive control in language selection makes language processing inherently different for bilinguals than it is for monolinguals. As such, selection between lexical competitors will be carried out differently by the two groups. Support for this claim comes from studies by Marian and colleagues who compared monolingual and bilingual performance on within-language

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phonological competition using both eye-tracking (Blumenfeld & Marian, 2011) and functional MRI (Marian, Chabal, Bartolotti, Bradley, & Hernandez, 2014). In the visual world paradigm, participants search for a target in a display of four pictures (or objects). On competitor trials, one of the pictures shares a phonological onset (e.g., candy) with the target (e.g., candle). Consistent with previous studies, more fixations were observed on phonological competitors than unrelated pictures for both monolinguals and bilinguals (Allopenna, Magnuson, & Tanenhaus, 1998; Desroches, Joanisse, & Robertson, 2006; Marian & Spivey, 2003). Blumenfeld and Marian further postulated that since the phonological distractor was a strong lexical competitor, it should require greater inhibition and produce larger negative priming effects in subsequent responses to that quadrant than would neutral pictures on a probe task. The authors found that the monolingual group, but not the bilingual group, was slower to identify the location of a gray asterisk among black asterisks when it was in the location previously occupied by the phonological distractor than they were for gray asterisks in a control location. Thus, larger negative priming was found for monolinguals than for bilinguals suggesting that bilinguals demonstrated better control by being able to disengage attention following the trial. Consistent with this interpretation, Marian et al. (2014), found that monolinguals showed greater recruitment of executive control regions (e.g., anterior cingulate, superior frontal gyrus) when performing the task, indicating more effortfulness. These studies demonstrate that monolinguals and bilinguals use different selection and inhibitory processes to understand isolated words, supporting the possibility for different engagement of EC resources in lexical processing.

Similar arguments can be applied to the way in which monolinguals and bilinguals process semantic competition. In the monolingual literature, semantic competition has been demonstrated by means of more fixations to semantic competitors in a visual world paradigm (e.g., Huettig & Altmann, 2005) and slower picture naming latencies following a semantic prime (e.g., Schriefers, Meyer, & Levelt, 1990). Yet little is known about how bilinguals resolve semantic competition. For bilinguals, several models assume a shared but language-independent semantic/conceptual store (e.g., Revised Hierarchical Model, Kroll & Stewart, 1994; Bilingual Interactive Activation model, Dijkstra & van Heuven, 2002; Distributed Lexical/Conceptual Feature Model, De Groot, 1992; see Francis, 2005 for a review). As such, the strength and nature of lexical links from each language to semantic knowledge may differ depending on specific linguistic knowledge, but simple semantic processing (e.g., is the object in this picture natural or man-made?) is likely to be comparable for monolinguals and bilinguals (Gollan, Montoya, Fennema-Notestine, & Morris, 2005). Nonetheless, selecting a concept for language production is not akin to simple semantic processing, since speakers must select between close yet competing alternatives and attach this concept to a word in one language.

Understanding how resolution of phonological and semantic competitors may differ for bilingual and monolingual listeners is important because it will provide insight into explaining the enhancement of EC found for bilinguals. Examining how conflict resolution unfolds in real time is best determined with event-related potentials (ERPs), a measure that is sensitive to online processing. Consequently, we utilized a speech perception task to examine processes that are used during language production, namely identifying pictures and assigning them labels. In the Picture Selection Task, each target picture (e.g., monkey) was paired with an alternative that was related semantically (e.g., gorilla), phonologically (e.g., money), or unrelated (e.g., belt). An auditory word was simultaneously presented and participants were required to select the named picture by means of a key press. Based on previous eye-tracking studies, related stimuli were expected to induce response competition (e.g., Allopenna et al., 1998; Blumenfeld & Marian, 2011). For semantic competition, both pictures must be recognized so the distinctive features for the target word can be identified and associated with an appropriate lexical label. For phonological competition, the target word must be interpreted in the correct language, but bilinguals need to attend to the phonological information relevant only for that language and possibly ignore the translation equivalents activated by the pictures. Thus, the nature of the competition from these two sources is expected to be substantially different from each other.

Given the novelty of the task, it is difficult to fully predict the electrophysiological outcomes, but extrapolation from previous ERP studies leads to several hypotheses. For semantically-related pairs, the most relevant ERP component is the N400. This component is sensitive to semantic and lexical mismatches between the stimulus and expectations such that mismatches are associated with larger negative amplitudes than matches (Kutas & Federmeier, 2011). In paradigms in which two semantically related pictures are presented either sequentially (Holcomb & McPherson, 1994; McPherson & Holcomb, 1999) or simultaneously (Zani et al., 2015), relatedness has resulted in less N400 negativity than found on unrelated pairs. This attenuation of the N400 for related primes has been interpreted as semantic integration (Holcomb & McPherson, 1994; Kutas & Federmeier, 2011). Presenting phonologically-related stimuli simultaneously has also been found to produce less negative waveforms than unrelated pairs (e.g., Dumay et al., 2001; Praamstra, Meyer, & Levelt, 1994). For example, Dell'Acqua et al. (2010) reported that electrophysiological responses to pictures with phonologically-related superimposed words (i.e., the picture name and word shared two or three initial phonemes) produced less negative waveforms from 250 to 450 ms than unrelated pairs.

The demands of the Picture Selection Task differ from priming tasks and relatedness judgments used in previous research where recognizing the relationship between stimuli aids responses. Consequently, phonological and semantic competition in the present case is expected to result in longer response times than will be found for unrelated stimuli. In the ERP data, it would be reasonable to hypothesize that greater negativity in the N400 would be observed in the presence of conflict. However, a study by Blackford, Holcomb, Grainger, and Kuperberg (2012) found a different pattern: when a semantically-related auditory prime preceded a picture, there was a reduced N400 but longer picture naming time than there was for an unrelated prime. The N400 indexed the perceived relationship between the prime and the target, but the recognition of the relationship interfered with their ability to make a verbal response. In the present paradigm, participants must also select between two related alternatives. Thus, it was hypothesized that for monolinguals, related pairs would produce both N400 attenuation and behavioral interference expressed as longer RTs.

A study by Kotz (1997) provides insight into potential group differences between monolinguals and bilinguals in their electrophysiological responses to related stimuli. Participants performed a visual lexical decision task that included a semantic priming manipulation, with primes presented at three SOAs. Monolinguals exhibited N400 attenuation for related prime-target pairs at all three SOAs but bilinguals exhibited a reduction in the N400 at SOAs of 200 ms and 800 ms but not at 0 ms when the target and prime were presented simultaneously. Kotz offered several possible explanations for this difference including less automatic spreading activation in bilinguals and insufficient time to access the meaning of both words in the L2. However, unlike longer SOAs, an SOA of 0 ms presents a problem of concurrent selection, a situation that may differentially impact bilinguals and monolinguals because it is similar to the bilingual experience in which concurrent selection is an ongoing processing requirement. The present study simulates this situation by asking participants to select between two pictures while an auditory cue is presented simultaneously. For monolinguals this results in selection between two lexical alternatives (e.g., fly, bee), but bilinguals must also consider the alternatives across languages (e.g., fly/*mouche*, bee/*abeille*). This greater selection demand for bilinguals may change the effect of stimulus relatedness for the bilinguals wherein they fail to integrate the relationship between pictures resulting in larger N400 negativity on the related pairs than is found for monolinguals.

In sum, the present studies used a novel paradigm to investigate whether bilinguals and monolinguals engage in similar selection processes during resolution of competing alternatives. The question is important because differences in such processes may be one of the mechanisms responsible for generalized advantages for bilinguals in nonverbal executive control. The hypothesis is that selecting between lexical options engages different processes for monolinguals and bilinguals, even when the task is carried out in a single language. Specifically, the expectation is that competition from within-language alternatives is more difficult to resolve and requires more executive control for bilinguals because of ongoing interference from the other language. Thus, it was hypothesized that both groups would experience behavioral interference in response to phonologically- and semantically-related pairs, but only monolinguals would exhibit N400 attenuation to related stimuli (cf., Kotz, 1997). The results will contribute to an understanding of potential differences in linguistic processing by monolinguals and bilinguals that may be relevant for the broader cognitive differences reported elsewhere.

## 2. Study 1

### 2.1. Method

#### 2.1.1. Participants

Fifty-six young adults participated in this study. Data from 3 participants were excluded due to poor EEG quality or technical difficulties. An outlier analysis led to the exclusion of one bilingual whose behavioral results were more than 3 SDs above the group mean. Thus, the final sample consisted of 26 monolingual and 26 bilingual participants. The monolinguals were native English speakers with only limited school exposure to a second language. The bilinguals spoke both English and one of the following languages fluently: Vietnamese (3), Spanish (3), French (3), Urdu (3), Gujarati (2), Hindi (2), Tamil (2), Arabic, Armenian, Cantonese, Danish, Polish, Romanian, Russian, or Serbian. Demographic and background measures are presented in Table 1. Participants received course credit for their participation.

#### 2.1.2. Tasks and procedures

*2.1.2.1. Peabody Picture Vocabulary Test-III (PPVT-A; Dunn & Dunn, 1997).* This is a standardized test of receptive English vocabulary knowledge. Participants identify which of four pictures corresponds to a spoken word. The standard score has a $\mu = 100$ and a $SD = 15$.

*2.1.2.2. Picture Selection Task.* One hundred and sixty black and white line drawings were selected from Cycowicz, Friedman, Rothstein, and Snodgrass (1997), Snodgrass and Vanderwart (1980), and the internet (see Table A.1 for picture names and Table A.2 for stimuli characteristics). There were 40 target pictures (e.g., monkey) and 40 of each of the three distractor types: semantically-related (e.g., gorilla), phonologically-related (onset overlap; e.g., money) and unrelated (e.g. belt). The task was programmed in E-prime and presented on a Dell 1908 FP Flat Panel monitor. Picture names were recorded by a female native-speaker of English using Audacity software (http://audacity.sourceforge.net/) and saved as 16 bit WAV files with a sampling rate of 44,000 Hz.

Each trial began with a fixation cross in the center of a white screen situated 60 cm from the participant. To control for anticipatory ERP artifacts, the fixation remained for either 500 or 1500 ms, after which two pictures appeared, one on either side of the cross. Each picture had a visual angle of 9.08°. Simultaneously, participants heard the name of one of the pictures and were asked to indicate as quickly and accurately as possible which picture was named by pressing the response key on the corresponding side of the display. Picture location was randomly generated by the program. The pictures disappeared after the response. Each target picture was presented six times, twice with each distractor. Within each pairing, the correct response was the target picture once and the distractor picture once. The latter were considered filler trials and were not analyzed.

#### 2.1.3. EEG recording

The electroencephalogram (EEG) was continuously recorded from 64 Ag–AgCl active electrodes that followed the International 10/20 system sites using the BioSemi Acquisition System (BioSemi ActiveTwo, Amsterdam). Six additional electrodes were used: one

**Table 1**
Demographic and background measures by language group for Studies 1–3.

| | Study 1 | | Study 2 | | Study 3 | |
|---|---|---|---|---|---|---|
| | Monolinguals ($n = 26$) | Bilinguals ($n = 26$) | Monolinguals ($n = 21$) | Bilinguals ($n = 20$) | Monolinguals ($n = 20$) | Bilinguals ($n = 25$) |
| Age | 20.7 (2.1) | 20.1 (1.8) | 23.6 (2.8) | 20.6 (2.5) | 19.3 (2.1) | 20.7 (2.7) |
| Mother's education | 3.3 (0.9) | 3.4 (1.3) | 3.2 (0.9) | 3.6 (1.1) | 2.9 (1.1) | 3.7 (1.0) |
| *Language use* | | | | | | |
| English as L1 (in %) | 100.0 | 15.4 | 100.0 | 30.0 | 100.0 | 20.0 |
| Age of L2 acquisition (in years) | – | 5.0 (3.5) | – | 3.9 (2.8) | – | 1.2 (1.8) |
| Home daily English use (in %) | 99.1 (2.7) | 44.5 (27.6) | 100.0 (0.0) | 62.4 (28.4) | 97.0 (11.3) | 38.9 (29.8) |
| *Language proficiency* | | | | | | |
| English PPVT | 104.4 (10.7) | 97.9 (13.4) | 104.3 (11.7) | 108.0 (7.9) | 103.9 (11.4) | 95.0 (12.3) |
| French PPVT | – | – | – | 100.0 (13.1) | – | – |
| English comp. rating[a] | 9.95 (0.2) | 9.50 (1.3) | 9.99 (0.5) | 9.64 (0.8) | 10.00 (0.0) | 9.66 (0.73) |
| English speaking rating[a] | 9.97 (0.2) | 9.33 (1.3) | 9.95 (1.9) | 9.34 (1.3) | 10.00 (0.0) | 9.02 (1.47) |
| Non-English comp. rating[a] | – | 8.82 (1.4) | – | 8.98 (1.1) | – | 9.18 (1.09) |
| Non-English speaking rating[a] | – | 7.97 (2.0) | – | 7.83 (1.6) | – | 8.92 (1.47) |
| Level of bilingualism[b] | 1.36 (0.6) | 4.40 (0.8) | 1.22 (0.4) | 4.50 (1.2) | 1.10 (0.3) | 4.31 (1.33) |

[a] Self-rated proficiency ratings are on a scale from 1 to 10.
[b] On the self-rated scale level of bilingualism, 1 = monolingual and 5 = fluent bilingual.

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 kΩ.

Off-line processing was performed using EEGLAB v10.2.2.4b toolbox under MATLAB v7.14 (2012, Mathworks, Natick, MA). The EEG was re-referenced offline to the average mastoid measurements. The EEG was segmented into epochs that were baseline-corrected (−200 ms to 0 ms) 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 μV. Eye movements and eye blinks were detected and corrected using the Independent Components Analysis (ICA; Makeig, Bell, Pung, & Sejnowski, 1996), a valid tool in preserving the brain activity of interest while "filtering" eye artifacts out of the signal (Mennes, Wouters, Vanrumste, Lagae, & Stiers, 2010). Remaining ocular artifacts were removed using a simple voltage threshold of 150 μV. Individual ERPs were created for each participant by electrode site and condition.

### 2.2. Results

#### 2.2.1. Background measures

Maternal education was measured on a 5-point Likert scale where 1 indicated no high school diploma, 2 was high school graduate, 3 was some college or college diploma, 4 was a bachelor's degree and 5 was a graduate or professional degree. There were no significant differences between monolinguals and bilinguals on age or maternal education, all *ps* > .20. Bilinguals scored somewhat lower on the English PPVT than monolinguals, $F(1,50) = 3.81$, $p = .057$ (cf., Bialystok & Luk, 2012). These results are shown in Table 1.

#### 2.2.2. Behavioral results

RTs longer than 3 s were removed from the analysis and then RTs 2.5 SDs greater than the individual's mean for each condition were also removed. This constituted the removal of 2.7% of the data for each language group. Accuracy analyses were conducted on square-root transformed errors in order to minimize the impact of any one participant (Myers, 1979). The mean RT and percentage error rates for each distractor type by language group are presented in Table 2.

A 2-way ANOVA on RTs for language group and distractor type (semantically-related, phonologically-related, unrelated) showed a main effect of distractor type, $F(2,100) = 192.64$, $p < .001$, $\eta_p^2 = .79$, in which all three conditions differed significantly (semantically related > phonologically related > unrelated), all *ps* < .001. There was no main effect of language group, $F < 1$, but there was a significant interaction of language group by distractor type, $F(2,100) = 3.80$, $p < .05$, $\eta_p^2 = .07$. However, none of the simple effects analyses revealed any pairwise comparisons that could account for the interaction. In the error analysis, there was a main effect of distractor type, $F(2,100) = 105.42$, $p < .001$, $\eta_p^2 = .68$, in which all three distractor types produced significantly different error rates (semantically related > phonologically related > unrelated), all *ps* < .001. Bilinguals made more errors than monolinguals, $F(1,50) = 3.97$, $p = .05$, $\eta_p^2 = .07$, with no interaction of distractor type by language group, $F < 1$.

**Table 2**
Mean RTs and percentage errors (and standard errors) on the Picture Selection Task by Language Group in Study 1.

| | Monolinguals | Bilinguals |
|---|---|---|
| *Reaction time (ms)* | | |
| Semantic | 1063 (28.6) | 1029 (29.3) |
| Phonological | 877 (17.4) | 892 (20.8) |
| Unrelated | 835 (13.0) | 854 (19.2) |
| *Percentage error* | | |
| Semantic | 10.1 (1.4) | 12.4 (1.5) |
| Phonological | 2.6 (0.4) | 3.8 (0.8) |
| Unrelated | 0.4 (0.2) | 1.3 (0.3) |

#### 2.2.3. EEG results

The task elicited a series of peaks that was largest over central-parietal electrode sites. ERP analyses focused on mean amplitude in the N400 time window (400–500 ms) at 12 electrode sites (FC1, FCz, FC2, C1, Cz, C2, CP1, CPz, CP2, P1, Pz, P2) arranged in a 3 lateral by 4 anterior–posterior grid (see montage in Fig. 1). The main interest was in potential processing differences between language groups on related pairs relative to unrelated pairs. Thus, separate analyses were done comparing language groups for phonological competition (phonological vs. unrelated) and semantic competition (semantic vs. unrelated). ERP waveforms for a representative electrode (CPz) are presented in Fig. 1. Only analyses that contained effects of distractor type and language group are reported. The Greenhouse-Geisser correction was applied to variables with more than one degree of freedom in the numerator. Only correct responses were included in these analyses.

In the analysis examining semantically-related and unrelated pairs, there were no main effects of language group, $F < 1$, or distractor type, $F(1,50) = 2.57$, $p = .12$, but there was a significant interaction between them, $F(1,50) = 4.14$, $p < .05$, $\eta_p^2 = .08$. Simple main effects analyses revealed that there was a reduced negativity of the N400 for the semantically-related pair relative to the unrelated pair for monolinguals, $F(1,50) = 6.62$, $p < .02$, $\eta_p^2 = .17$, but not for bilinguals, $F < 1$. That is, the monolinguals showed attenuation of the N400 in response to semantic relatedness. No other effects were significant, all *ps* > .24.

In the phonological competition analysis, there were no main effects of either language group or distractor type, both *F*s < 1. There was a marginal interaction of language group by distractor type, $F(1,50) = 3.70$, $p = .06$, $\eta_p^2 = .07$. Bilinguals exhibited marginally larger N400s for phonologically-related pairs than unrelated pairs, $F(1,50) = 3.41$, $p = .07$, $\eta_p^2 = .06$. No differences were observed in the monolingual group, $F < 1$. No other effects approached significance, all *ps* > .13.

### 2.3. Discussion

Study 1 examined the neural underpinnings of lexical selection in bilinguals and English monolinguals. Behaviorally, both groups were slower to identify the target in the presence of related distractors than unrelated distractors, with semantically-related lures producing the slowest responses and phonologically-related lures faster than these but still slower than unrelated pairs. These data demonstrate that during response selection, both groups were sensitive to the relationship between the pictures, and similarity interfered with speed of selection. The lack of behavioral group differences is consistent with work by Marian and colleagues (Blumenfeld & Marian, 2011; Marian et al., 2014) who argued that motor responses may not be sufficiently sensitive to capture between-group differences.

Where the groups differed was in how they processed the semantic competition as shown in the electrophysiological data. Specifically, monolinguals exhibited less negativity in the N400 for the semantically-related condition than in the unrelated condi-

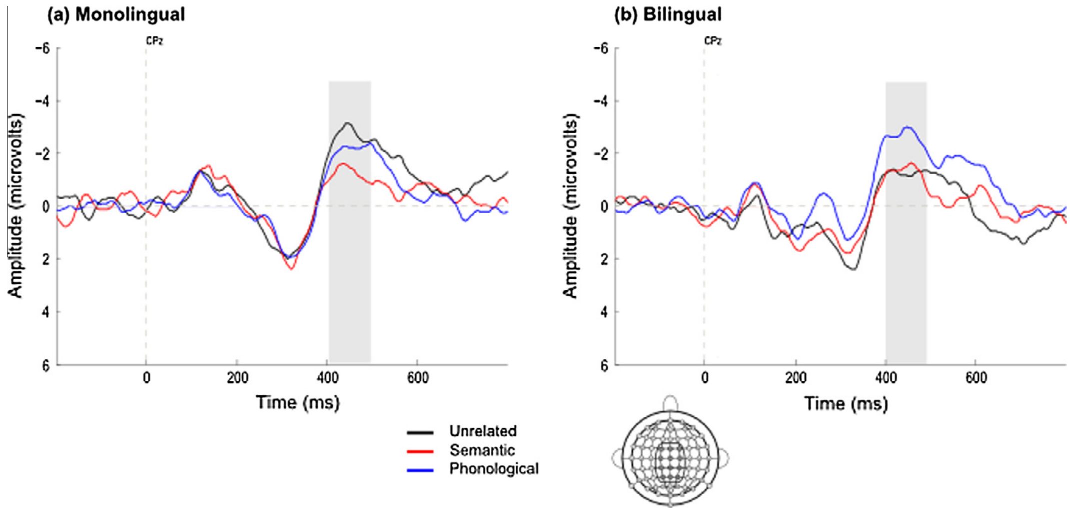


**Fig. 1.** Grand-averaged ERPs on the CPz electrode for the unrelated (black), semantic (red), and phonological (blue) conditions of the (a) monolingual group and (b) bilingual group in Study 1. The gray shaded area represents the N400 time-window.

tion while bilinguals did not. Attenuation of the N400 in response to a semantic relationship is consistent with results of monolingual studies using pictures (e.g., Chauncey, Holcomb, & Grainger, 2009; McPherson & Holcomb, 1999; Zani et al., 2015), but few studies have shown N400 attenuation coupled with longer RTs. Blackford et al. (2012) suggested that the N400 indexes how the semantic relationship is perceived and integrated (i.e., automatic electrophysiological semantic priming) but does not directly reflect the factors involved in later response selection. However, if this were the full explanation, then the bilinguals should have also have shown N400 attenuation to the semantic relationship as they have in studies using semantic priming (Duñabeitia, Dimitropoulou, Uribe-Etxebarria, Laka, & Carreiras, 2010; Kerkhofs, Dijkstra, Chwilla, & de Bruijn, 2006; Kotz & Elston-Güttler, 2004). Yet, in both the current study and Kotz (1997), simultaneous presentation of related stimuli did not produce N400 attenuation for bilinguals.

To explain these findings, consider that the N400 indexes automatic semantic integration but is also modulated by attention (see Kutas & Federmeier, 2011 for a review). Since bilinguals activate lexical alternatives from both languages, the two presented items may not be integrated because they do not exhaust the possibilities for bilinguals, specifically, the jointly-activated labels from their other language. Consequently, uncertainty remains for the bilinguals because the two pictures are not fully integrated by the word in a single language. This situation would result in the lack of N400 attenuation observed in the semantic condition for the bilinguals.

Unlike the semantic analysis, the electrophysiological effects in the phonological analysis failed to reach significance. The behavioral effect in this condition was smaller than in the semantic manipulation confirming that it was a subtler manipulation. Blackford et al. (2012) also failed to observe a significant phonological ERP effect despite significant behavioral effects. One possibility is that the heterogeneous language backgrounds of the bilinguals may have masked group differences because of variability from multiple cross-language alternatives. This possibility was addressed in Study 2.

## 3. Study 2

The interpretation for the results in Study 1 was that bilinguals needed to manage conflict from their non-English language as well as the conflict introduced by the relation between the pictures, so deciding between semantically-related alternatives was more effortful and involved more executive control than it did for monolinguals. However, because the bilinguals were linguistically heterogeneous, the potential phonological competition from the non-English words was unknown. Therefore, to have a more precise understanding of the competition on each trial, a second study was performed in which the bilinguals were all English–French bilinguals, making the non-English label transparent. These participants performed the Picture Selection Task in both English and French. A fourth condition was added to evaluate the effect of between-language phonological interference in which the target picture was phonologically-related to the translation of the distractor.

### 3.1. Method

#### 3.1.1. Participants

Fifty-two young adults participated in this study. Data from nine participants were excluded due to poor EEG quality. One bilingual and one monolingual participant were excluded because their behavioral effects were at least 3 SD outside the group mean. The final sample consisted of 21 monolingual and 20 bilingual participants. The monolinguals were native English speakers with only limited school exposure to a second language. The English–French bilinguals had either French at home (10 out of 20 participants) and/or had been enrolled in a French immersion program from elementary to the end of high school (18 out of 20 participants). Sixteen bilinguals indicated some minimal knowledge of a third language. Demographic and background measures are shown in Table 1. The bilinguals were tested in counterbalanced English and French sessions one week apart. The monolinguals only completed the English session.

#### 3.1.2. Tasks and procedures

*3.1.2.1. Peabody Picture Vocabulary Test-III (PPVT; Dunn & Dunn, 1997).* The procedures for the English PPVT were the same as those described in Study 1. To measure French receptive vocabulary in the bilingual group, the target words from Form-B of the PPVT were translated into French[1] and administration followed the same

[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, and 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.

procedures as for the English version. Bilinguals performed both language versions, with instructions provided in the target language.

*3.1.2.2. Picture Selection Task.* The English Picture Selection Task was modified to include a between-language phonological condition ("phonological-between") in which the target picture was phonologically-related to the translation of the distractor. For example, *moose* was paired with *windmill* as its distractor, since the French word for *windmill* is *moulin*. This manipulation is similar to that used by Marian and Spivey (2003) in their eye-tracking study: Russian–English participants performing the task in English had to make an eye movement to an item such as a marker when one of the distractors was a stamp, called "marka" in Russian. In their study, the cross-language phonological distractor created interference. A French version of the task was also created and administered to the bilinguals (see Tables B.1 and B.2 for the English and French stimuli, respectively, and Table B.3 for word characteristics). Each word was recorded by female native speakers of each language using Audacity 2.0 at a sampling rate of 44.1 kHz. Each picture was formatted to be 5.9° in visual angle. The EEG recording procedures from Study 1 were implemented.

## 3.2. Results

### 3.2.1. Background measures

Mean scores and standard deviations for the background measures are reported in Table 1. There were no significant differences between groups on maternal education, $F < 1$, or English PPVT score, $F(1,39) = 1.41$, $p = .24$. Bilinguals obtained higher scores on English PPVT than on the French PPVT, $F(1,19) = 9.74$, $p < .01$, $\eta_p^2 = .34$. However, if these scores are examined separately for those bilinguals who spoke French at home ($n = 10$, English PPVT = 106.5, French PPVT = 102.5) and those who did not ($n = 10$, English PPVT = 109.5, French PPVT = 97.4), the difference between English and French scores was not significant for the first, $t(9) = 1.15$, n.s., but was significant for the second, $t(9) = 3.43$, $p < .01$.

### 3.2.2. Behavioral results

RTs longer than 3 s were removed from the analysis and RTs 2.5 SDs greater than the individual's mean for each distractor type were also removed. In the English task, this constituted the removal of 2.7% and 2.6% of the data for the monolinguals and bilinguals, respectively. In the French task, 2.6% of the data was removed. Accuracy analyses were conducted on square-root transformed error rates. The mean RTs and percentage error rates for each distractor type by language group are presented in Table 3.

For the English task, a 2-way ANOVA on RTs for language group and distractor type (semantic, phonological-within, phonological-between, unrelated) showed a main effect of distractor type, $F(3,117) = 143.92$, $p < .001$, $\eta_p^2 = .79$, in which the semantic distractor produced significantly longer RTs than the phonological-within distractor, $p < .001$, which in turn produced longer RTs than the unrelated distractor, $p < .02$. The phonological-between distractor did not differ significantly from the phonological-within or the unrelated distractors. This replicates the pattern found in Study 1, with the new distractor, phonological-between, not forming a distinct category but situated between the phonological and unrelated conditions. In the error analysis, there was a main effect of distractor type, $F(3,117) = 84.01$, $p < .001$, $\eta_p^2 = .68$, in which the semantic distractor produced more errors than the phonological-within distractor, $p < .001$, and the phonological-within produced significantly more errors than the phonological-between distractor, $p < .02$. Again, the phonological-between and unrelated distractors did not differ significantly from each other. Neither the main effect of language group nor the distractor type by language group interaction was significant, $Fs < 1$.

**Table 3**
Mean RTs and percentage errors (and standard errors) on the Picture Selection Task by Language Group and Language in Study 2.

| | Monolinguals | Bilinguals |
|---|---|---|
| English | | |
| *Reaction time (ms)* | | |
| Semantic | 954 (30.2) | 932 (30.9) |
| Phonological-within | 770 (24.2) | 749 (24.8) |
| Phonological-between | 755 (18.1) | 727 (18.5) |
| Unrelated | 741 (19.5) | 732 (20.0) |
| *Percentage error* | | |
| Semantic | 10.4 (1.3) | 9.6 (1.4) |
| Phonological-within | 1.6 (0.7) | 2.7 (0.8) |
| Phonological-between | 0.8 (0.4) | 1.0 (0.4) |
| Unrelated | 0.9 (0.4) | 1.0 (0.4) |
| French | | |
| *Reaction time (ms)* | | |
| Semantic | – | 919 (31.0) |
| Phonological-within | – | 781 (23.1) |
| Phonological-between | – | 771 (18.9) |
| Unrelated | – | 759 (18.9) |
| *Percentage error* | | |
| Semantic | – | 11.0 (1.3) |
| Phonological-within | – | 3.6 (0.6) |
| Phonological-between | – | 3.0 (0.7) |
| Unrelated | – | 1.5 (0.6) |

To compare performance on the English and French tasks for bilinguals, a 2-way ANOVA on RT was conducted with task language and distractor type as within-subject factors. There was no main effect of task language, $F(1,19) = 1.94$, $p = .18$, but there was a main effect of distractor type, $F(3,57) = 117.56$, $p < .001$, $\eta_p^2 = .86$, in which semantically-related pairs produced longer RTs than all the other conditions (all $ps < .001$), with no differences between the other conditions. In the error analysis, there was a main effect of distractor type, $F(3,57) = 62.18$, $p < .001$, $\eta_p^2 = .77$, in which the semantically-related pairs produced more errors than all other conditions, $ps < .001$, and the phonological-within produced more errors than the unrelated condition, $p < .01$. There was a main effect of task language, $F(1,19) = 5.81$, $p < .05$, $\eta_p^2 = .23$, in which more errors were produced in French than in English. The interaction between task language and distractor type was not significant, $F < 1$. Follow-up RT analyses comparing the subsets of bilinguals in terms of the presence of French at home revealed no main effect of language background, $F < 1$, and no interactions of language background with task language or distractor types, all $ps > .51$. For the error rates, there was no main effect of language background, $F < 1$, and no interaction of language background with the other variables, all $ps > .31$.

### 3.2.3. ERP results

ERP waveforms were analyzed using the same electrode sites and time window (N400: 400–500 ms) as Study 1. To examine each type of competition as a function of language group in the English task, three 4-way ANOVAs for language group, condition, laterality, and anteriority were conducted. Only effects that include distractor type are reported. The ERP waveform for the monolingual group is presented in Fig. 2a and the ERP waveforms for the bilingual group performing the task in English and French are presented in Fig. 2b and c, respectively.

In the analysis comparing semantically-related to unrelated pairs, there was no main effect of language group, $F(1,39) = 2.85$, $p = .10$, but there was a marginal effect of distractor type, $F(1,39) = 3.72$, $p = .06$, $\eta_p^2 = .09$, and a marginal language group by distractor type interaction, $F(1,39) = 3.08$, $p = .08$, $\eta_p^2 = .07$. Because these values were close to standard levels of significance and there were a priori reasons to expect the direction of the interaction, simple

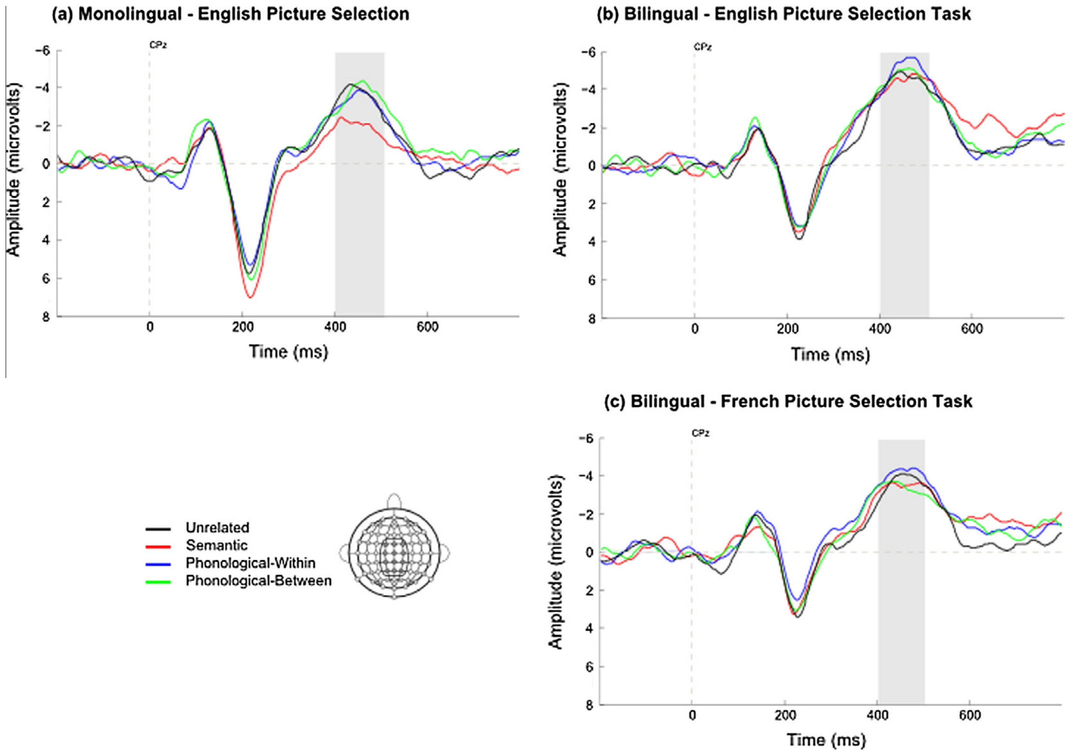


**Fig. 2.** Grand-averaged ERPs on CPz electrode for the unrelated (black), semantic (red), phonological-within (blue) and phonological-between (green) conditions of the (a) monolingual group, (b) bilingual group performing the English task, and (c) bilingual group performing the French task in Study 2. The shaded gray area represents the N400 time-window.

effects analyses were conducted. The simple main effects revealed that there was reduced N400 negativity on the semantically-related distractor condition relative to the unrelated condition for monolinguals, $F(1,20) = 6.41$, $p = .02$, $\eta_p^2 = .24$, but not for bilinguals, $F < 1$. No other effects were significant, all $ps > .10$.

For the phonological-within distractor analysis, there were no main effects of language group, $F(1,39) = 1.97$, $p = .17$, distractor type, $F < 1$, or their interaction, $F < 1$. No other effects were significant, all $ps > .13$. For the phonological-between distractor analysis, there was no main effect of language group, $F(1,39) = 1.44$, $p = .24$, distractor type (phonological-between and unrelated), $F < 1$, or their interaction, $F < 1$. No other effects were significant, all $ps > .26$.

A series of analyses on the N400 in the bilingual group comparing language (English and French) by distractor type (semantic and unrelated; phonological-within and unrelated; phonological-between and unrelated) showed no differences between the English or French version of the task, all $ps > .17$. Follow-up analyses comparing language background (English–French bilinguals who had French in the home versus those who did not) by task language and distractor type revealed no main effect of language background, all $Fs < 1$, and no interactions of language background with distractor type or task language, all $ps > .31$.

### 3.3. Discussion

Two main results from Study 1 were replicated with a linguistically-homogenous group of bilinguals performing the task in English. First, the phonological-within and semantic conditions produced longer RTs and more errors than the unrelated condition for both language groups. Second, significant N400 attenuation was observed for the semantically-related condition for the monolinguals in English but not for the bilinguals in either language. The relation between the two pictures is therefore critical for the response and the conceptual overlap between the pictures in the semantically-related condition led to a reduced N400 for monolinguals. Thus, in two studies, monolinguals but not bilinguals showed evidence of integrating the semantically-related pictures in the presence of the auditory cue. These results replicate those found by Kotz (1997) in a semantic priming paradigm when the two words were presented concurrently (SOA of 0 ms). In her study, monolinguals but not bilinguals exhibited a reduced N400 on the semantically-related pairs. Kotz's explanation was weaker L2 proficiency and slower spreading activation speed in bilinguals. However, this explanation is unlikely to apply to the results of Study 2 since bilinguals and monolinguals obtained equivalent scores on English vocabulary knowledge and no differences were observed between bilinguals who had learned French at home and those who had English at home and learned French in an immersion program. A more likely explanation is that the electrophysiological differences reflect different selection demands for the bilinguals.

No significant phonological effects in the electrophysiological data were observed in Study 2. One possibility is that the simultaneous presentation of the auditory cue and the pictures allowed insufficient time for competition to build at the word-phoneme level before the correct picture was identified. Consistent with this idea, previous research that has found within-language phonological competition effects using both ERP (Desroches, Newman, & Joanisse, 2009) and eye-tracking (Blumenfeld & Marian, 2011) employed a paradigm in which there was a delay between the presentation of the pictures and the auditory cue. In Desroches et al.'s paradigm, participants saw a picture and after a delay heard an auditory cue that either matched or mismatched the picture. Mismatches produced larger N400s than matches, with the largest amplitude observed when the auditory cue shared an onset (e.g., candle) with the name of the picture (e.g., candy) (an onset mismatch). This methodology enables participants to assign a label to the pictures, generate expectations about the upcoming auditory cue and hold them in memory before being required to make a lexical selection.

## 4. Study 3

The goal of Study 3 was to investigate the locus of group differences in processing semantic competition. In Studies 1 and 2, the pictures and auditory cue were presented simultaneously, creating a situation in which three stimuli needed to be processed. Consequently, the differences in semantic processing between language groups may have been due to how participants processed the relation between the pictures or how they processed the triad, which consisted of the two pictures and the auditory cue. To distinguish between these possibilities, Study 3 removed the auditory cue from the triad by presenting it 800 ms after the picture onset to examine how the relation between the pictures is processed. If the semantic differences observed in Studies 1 and 2 were due to the relationship between the pictures and the word, then removing the word should lead to semantic integration and N400 attenuation for all participants. However, if the differences in the first two studies reflected the failure of bilinguals to process the conceptual similarity between the pictures, then removing the auditory cue will not change the results and bilinguals will again show no attenuation of the N400.

### 4.1. Method

#### 4.1.1. Participants

Twenty-five monolinguals and 29 bilinguals were recruited. Data from nine participants (5 monolinguals and 4 bilinguals) were excluded due to poor EEG quality. The final sample consisted of 20 monolinguals and 25 bilinguals. The monolinguals were native English speakers with only limited school exposure to a second language. The bilinguals spoke English and one of the following languages fluently: Cantonese (4), Mandarin (4), Farsi (4), Polish (2), Punjabi (2), Russian (2), Spanish (2), Arabic, Greek, Gujarati, Korean or Serbian. Demographic and background measures are presented in Table 1. Participants received course credit for their participation.

#### 4.1.2. Tasks and procedures

*4.1.2.1. Peabody Picture Vocabulary Test-III (PPVT; Dunn & Dunn, 1997).* This is the same measure employed in Studies 1 and 2.

*4.1.2.2. English Picture Selection Task.* The task stimuli and procedure were modified from Study 2. Specifically, the phonological-between-language condition was removed and the auditory cue was presented 800 ms after the two pictures were presented.

### 4.2. Results

#### 4.2.1. Background measures

Mean scores and standard deviations for background measures are reported in Table 1. Bilinguals reported higher maternal education, $F(1,44) = 7.29$, $p = .01$, than monolinguals but scored lower on English PPVT, $F(1,44) = 6.21$, $p < .02$.

#### 4.2.2. Behavioral results

The same trimming procedures from Studies 1 and 2 were used, leading to the removal of 2.3% and 2.5% of the data for monolinguals and bilinguals, respectively. The mean RTs and error rates for each distractor type by language group are presented in Table 4.

**Table 4**
Mean RTs and percentage errors (and standard errors) on the Picture Selection Task by Language Group in Study 3.

| | Monolinguals | Bilinguals |
|---|---|---|
| *Reaction time (ms)* | | |
| Semantic | 742 (24.0) | 790 (27.3) |
| Phonological | 702 (18.3) | 727 (15.5) |
| Unrelated | 654 (15.8) | 672 (15.5) |
| *Percentage error* | | |
| Semantic | 7.2 (1.0) | 7.2 (0.9) |
| Phonological | 4.4 (0.7) | 6.1 (0.8) |
| Unrelated | 0.4 (0.2) | 0.8 (0.2) |

A 2-way ANOVA on RTs for language group and distractor type showed no main effect of language group, $F(1,43) = 1.30$, $p = .26$. There was a main effect of distractor type, $F(2,86) = 64.83$, $p < .001$, $\eta_p^2 = .60$, in which the semantic condition produced significantly longer RTs than the phonological condition, which in turn produced longer RTs than the unrelated condition, $ps < .001$. The interaction of language group by distractor type was not significant, $F(2,86) = 1.66$, $p = .21$. In the error analysis, there was a main effect of distractor type, $F(2,86) = 57.80$, $p < .001$, $\eta_p^2 = .57$, such that the semantic condition produced more errors than the phonological condition, $p < .001$, and the phonological condition produced more errors than the unrelated condition, $p < .001$. The main effect of language group and the interaction of language group by distractor type were not significant, $Fs < 1$.

#### 4.2.3. ERP results

ERPs were time-locked to the presentation of the pictures. The analyses were conducted on the picture-onset N400 (400–600 ms) and on the auditory-onset N400 (1150–1300 ms). For the picture-onset N400, 12 electrode sites (F1, Fz, F2, FC1, FCz, FC2, C1, Cz, C2, CP1, CPz, and CP2) in a 3 lateral by 4 anterior–posterior grid were analyzed. A fronto-central N400 effect was observed, consistent with the literature showing that the effect is more frontally-distributed for pictures than words (Giorgio, Kutas, & Sereno, 1996). For the auditory-onset N400, analyses were performed at 12 more posteriorly located electrode sites (FC1, FCz, FC2, C1, Cz, C2, CP1, CPz, CP2, P1, Pz, and P2) in a 3 lateral by 4 anterior–posterior grid. The ERP waveforms are presented in Fig. 3a for the monolingual group and Fig. 3b for the bilingual group. Only effects that contained distractor type and language group are reported.

Analysis of the semantic picture-onset N400 mean amplitudes revealed a main effect of semantic relatedness, $F(1,43) = 4.19$, $p < .05$, $\eta_p^2 = .09$, indicating a smaller N400 amplitude for semantically-related than unrelated pairs. There was no main effect of group, $F(1,43) = 2.37$, $p = .13$, and no group by distractor type interaction, $F < 1$. There was a significant interaction of group by anteriority by condition, $F(3,129) = 4.69$, $p = .02$, $\eta_p^2 = .10$. Simple main effects analyses of the 3-way interaction revealed that the semantic effect was larger at frontal electrode sites for the monolinguals and at posterior sites for the bilinguals. Analysis of the auditory-onset N400s (1100–1300 ms) time window mean amplitudes for the semantic condition revealed no main effect of language group, distractor type, or language group by distractor type interaction, all $ps > .18$. Taken together, the semantic effect was observed only during picture-onset for both groups, indicating that in the absence of a concurrent auditory cue, bilinguals integrated the semantic relationship between the pictures similarly to the monolinguals.

Analysis of the phonological picture-onset N400 mean amplitudes revealed no main effect of language group, $F(1,43) = 2.59$,

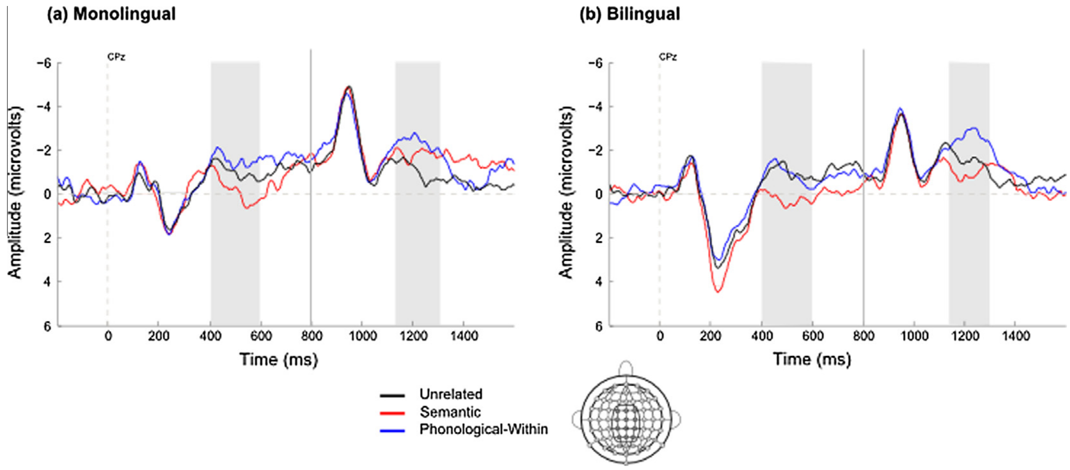


**Fig. 3.** Grand-averaged picture-onset and auditory-onset ERPs on the CPz electrode for the unrelated (black), semantic (red), and phonological (blue) conditions of the (a) monolingual group and (b) bilingual group in Study 3. The vertical line indicates the time when the auditory word is presented. The shaded gray areas represent the N400 time-window for the picture-onset and auditory-onset.

$p = .12$, distractor type, $F < 1$, or language group by distractor type interaction, $F < 1$. Analysis of the 1150–1300 ms time window representing the auditory-onset N400 showed a main effect of distractor type, $F(1,43) = 4.18$, $p < .05$, $\eta_p^2 = .09$, in which there was a larger amplitude for the phonological condition than for the unrelated condition. There was no main effect of language group or interaction of language group by distractor type, *F*s < 1. Thus for phonological distractors, there was no impact of the shared phonology during the picture-onset; however both groups required greater cognitive effort, as evidenced by larger N400s, to differentiate the target from the phonological distractor once the auditory cue was presented.

### *4.3. Discussion*

The behavioral results in this study replicated the patterns found in the first two studies showing longer RTs and more errors for semantically-related than for phonologically-related pairs and for phonologically-related pairs than for unrelated pairs. Moreover, by modifying the task to create a delay between presentation of the pictures and the auditory cue, the locus of the semantic processing differences observed in Studies 1 and 2 could be attributed to the integration of the two pictures with the auditory cue, since both bilinguals and monolinguals exhibited N400 attenuation in response to semantically-related pictures. The longer SOA also increased the degree of phonological competition, leading to greater negativity on the auditory-onset N400 in the phonological condition relative to the unrelated condition.

Significant electrophysiological effects were found for both the picture-onset N400 and auditory-onset N400. For the picture-onset N400, monolinguals and bilinguals exhibited attenuation of the N400 in the semantically-related condition, indicating semantic integration of the pictures. Thus, it is likely that the group differences observed in the N400 in Studies 1 and 2 reflected the need to further integrate the pictures with the concurrently-presented word. The results in Study 3 are consistent with the N400 attenuation that Kotz (1997) observed for bilinguals when an 800 ms SOA was inserted between semantically-related stimuli. Taken together, these results suggest that when the processing demands associated with simultaneous pictorial and auditory processing are reduced, bilingual semantic processing is similar to that of monolingual processing.

For the picture-onset, there was no effect of the phonological distractor in the electrophysiological data, suggesting that participants were not immediately identifying the phonological relationship between the pictures. However, once the auditory cue was presented, the phonological condition produced larger N400s than the unrelated condition, indicating that more processing was necessary to distinguish between pictures that share onsets. Importantly, in this condition the listener must wait for the word to unfold for the uniqueness point (e.g., mon**k**ey vs. mon**e**y) to be reached before determining which picture is the target. Additionally, the 800 ms SOA enabled participants to identify both picture names and hold them in memory while waiting for the auditory cue. The larger N400 after the auditory cue in the phonological distractor condition suggests that this manipulation resulted in increased phonological competition. This result is consistent with work by Desroches et al. (2009) who found that when an auditory cue mismatched a single picture, larger N400s were observed for onset mismatches than for unrelated mismatches. Although it is surprising that no language group differences were observed at the electrophysiological level in either Study 2 or 3 during initial word processing, these results are consistent with Blumenfeld and Marian (2011) who only observed group differences in the follow-up probe task after word processing had occurred.

## 5. General discussion

The main question motivating the study was to determine whether lexical selection by monolinguals, for example choosing between "cup" or "mug", was based on similar processing as used in bilingual selection across languages, for example saying "cup" or "*tasse*". The intention was to investigate the uniqueness of the cross-language situation for bilinguals to provide support for the plausibility of its role in underlying the advantages found for bilinguals in other forms of conflict resolution. Since only bilinguals experience cross-language conflict, the question could only be studied indirectly by comparing monolinguals and bilinguals within the same language. The reasoning was that if the selection among competitors within a language was performed similarly by monolinguals and bilinguals, then the unique situation of cross-language selection for bilinguals was unlikely to serve as an explanation for bilingual advantages in nonverbal executive control because the same outcomes should be available to monolinguals as a consequence of the choices made for within-language competitors.

To investigate this question, a novel paradigm was developed and three main findings were observed. First, both bilinguals and monolinguals were slower to identify the target picture in the presence of related distractors than an unrelated distractor, with the longest response times observed to targets in the presence of semantically-related lures. Second, despite comparable behavioral responses, only the monolinguals exhibited reduction in the N400 amplitude for semantically-related pictures, indicating they were integrating the relationship between the pictures and auditory cue (Studies 1 and 2). The bilinguals, in contrast, produced no differences in the N400 amplitude for trials in which the pictures were semantically related and unrelated (Studies 1 and 2). Third, when an 800 ms SOA was inserted between the pictures and the auditory cue, both bilinguals and monolinguals produced evidence for semantic integration in the picture-onset N400 and exhibited greater negativity in the phonological condition in the auditory-onset N400 (Study 3). Importantly, the speed with which listeners must contend with linguistic labels during natural language use is more similar to the timing used in Studies 1 and 2 than the artificial delay used in Study 3, supporting the interpretation that competition for concurrent selection is different for monolinguals and bilinguals during natural language processing.

The precise mechanisms responsible for the observed differences in the selection processes are not fully understood. Nonetheless, Studies 1 and 2 provide insight into the role of the relation between the languages and English language proficiency. Since the two studies produced similar results, it seems unlikely that these two variables meaningfully impacted the pattern of results. In both studies, bilinguals showed no attenuation from semantic relatedness, and in Study 2, bilinguals did not differ significantly from the monolinguals on English vocabulary knowledge, ruling out English proficiency as an explanation.

Our interpretation is that the joint activation of languages for bilinguals means they have more options to consider when making simple lexical choices than do monolinguals. For monolinguals, selecting between two semantically-related pictures to match a word that named one of them showed a reduction in N400 amplitude, the signature of reduced conflict, but for bilinguals, the conflict remained. This failure to integrate semantically-related stimuli reflects greater conflict and potentially the need to recruit greater EC. Our interpretation is that the presented word left outstanding lexical possibilities, presumably those from the other language, so complete integration was not possible. Removing the word and asking participants only to evaluate two pictures, in contrast, produced similar results for everyone – if there was a conceptual relationship between the pictures there was a reduction in the N400. Similarly, Gollan et al. (2005) found no language group differences on a simple semantic classification task based on pictures, but bilinguals were slower than monolinguals when required to assign labels to the pictures. Thus, these results are consistent with the assertions from language models that bilinguals have a shared language-independent conceptual store (e.g., Dijkstra & van Heuven, 2002; Kroll & Stewart, 1994) and that semantic processing in the absence of language does not differ for monolinguals and bilinguals. Evidence for greater conflict for bilinguals during language processing is consistent with the possibility that this ongoing management of lexical conflict distinguishes monolinguals from bilinguals and may in turn be at least part of the mechanism by which conflict resolution in bilinguals is enhanced, even for nonverbal tasks. We acknowledge that our results provide only indirect evidence for this claim but the convergence of the results and the theoretical predictions make the interpretation plausible.

In sum, the present evidence shows clear differences in how monolinguals and bilinguals make simple choices in a single language. These differences are consistent with explanations of enhanced bilingual performance in nonverbal conflict tasks that trace the source to the constant conflict that is part of bilingual language use. Thus, choosing between "cup" and "mug" for a monolingual is not an analog of what bilinguals do every time they choose a word to speak where the options represent different languages. Therefore, the routine selection choices made by monolinguals have no implications for the enhancement of executive control.

## Acknowledgments

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## Appendix A

See Tables A.1 and A.2.

**Table A.1**
Stimuli used in Study 1.

| Target | Phonological | Semantic | Unrelated |
|---|---|---|---|
| Banjo | Bandage | Guitar | Apple |
| Beaver | Beard | Otter | Skirt |
| Bee | Beer | Fly | Foot |
| Beetle | Beach | Ant | Whistle |
| Boat | Bowl | Cruise | Iron |
| Boot | Book | Shoe | Spoon |
| Bottle | Box | Glass | Frog |
| Butterfly | Button | Moth | Church |
| Candy | Candle | Chocolate | Plug |
| Canoe | Cannon | Kayak | Swan |
| Chair | Chain | Stool | Bread |
| Cherries | Chest | Grapes | Lion |
| Chicken | Chimney | Rooster | Bed |
| Clown | Cloud | Joker | Leaf |
| Coffee | Coffin | Tea | Lock |
| Comb | Cone | Brush | Mushroom |
| Desk | Desert | Table | Hat |
| Dolphin | Doll | Shark | Pitcher |
| Dummy | Duck | Mannequin | Stove |
| Flamingo | Flag | Pelican | Barrel |
| Glove | Globe | Mitten | Fox |
| Hammer | Hammock | Gavel | Onion |
| Horse | Horn | Donkey | Drum |
| Jacket | Jam | Coat | Lamp |
| Knife | Knight | Sword | Well |
| Lemon | Leopard | Orange | Airplane |
| Monkey | Money | Gorilla | Belt |
| Moose | Moon | Deer | Window |
| Mountain | Mouse | Cliff | Ring |
| Peacock | Peanut | Ostrich | Glasses |
| Penguin | Pen | Owl | Hanger |
| Pineapple | Pipe | Coconut | Nail |
| Sheep | Shield | Goat | Piano |
| Skunk | Skull | Raccoon | Cake |
| Squirrel | Squid | Chipmunk | Ear |
| Toe | Toaster | Finger | Bear |
| Truck | Trumpet | Bus | Crown |
| Tulip | Tooth | Rose | Car |
| Turnip | Turkey | Carrot | Harp |
| Wheel | Wheat | Tire | Clock |

**Table A.2**
Word characteristics for stimuli used in Study 1.

| Word type | Word frequency | Word length | # of phonemes | Orthographic neighborhood | Phonological neighborhood |
|---|---|---|---|---|---|
| Target | 24.4 | 5.7 | 4.5 | 3.0 | 8.1 |
| Unrelated | 43.8 | 4.7 | 3.9 | 7.1 | 12.8 |
| Semantic | 20.4 | 5.4 | 4.2 | 3.6 | 9.4 |
| Phonological | 31.0 | 5.1 | 4.0 | 4.7 | 13.3 |

*Note*. Word frequency statistics are based on the Kucera–Francis database.

## Appendix B

See Tables B.1–B.3.

**Table B.1**
English stimuli used in Study 2.

| Target | Phonological-within | Phonological-between | 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 |

**Table B.2**
French stimuli used in Study 2.

| Target | Phonological-within | Phonological-between | 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 |

(continued on next page)

**Table B.2** (*continued*)

| Target | Phonological-within | Phonological-between | Semantic | Unrelated |
|---|---|---|---|---|
| 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 |

**Table B.3**
Word characteristics for stimuli used in Study 2.

| Language | Word type | Word frequency | Word length | # of phonemes | Orthographic neighborhood | Phonological neighborhood |
|---|---|---|---|---|---|---|
| English | Target | 24.2 | 5.3 | 3.9 | 5.8 | 12.3 |
| | Unrelated | 27.8 | 5.3 | 4.2 | 4.1 | 8.8 |
| | Semantic | 42.7 | 5.4 | 4.2 | 4.3 | 10.0 |
| | Phono-within | 34.2 | 5.1 | 4.1 | 6.3 | 14.0 |
| | Phono-between | 32.5 | 5.4 | 4.0 | 5.7 | 12.7 |
| French | Target | 45.4 | 6.0 | 4.2 | 3.5 | 10.7 |
| | Unrelated | 43.6 | 6.3 | 4.6 | 2.7 | 6.3 |
| | Semantic | 25.4 | 5.7 | 4.2 | 3.7 | 9.1 |
| | Phono-within | 49.3 | 6.8 | 4.5 | 3.4 | 9.6 |
| | Phono-between | 53.4 | 6.9 | 4.7 | 3.1 | 6.9 |

*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.

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