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Electrophysiological assessment of the time course of bilingual visual word recognition: Early access to language membership

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A B S T R A C T

Previous research examining the time course of lexical access during word recognition suggests that phonological processing precedes access to semantic information, which in turn precedes access to syntactic information. Bilingual word recognition likely requires an additional level: knowledge of which language a specific word belongs to. Using the recording of event-related potentials, we investigated the time course of access to language membership information relative to semantic (Experiment 1) and syntactic (Experiment 2) encoding during visual word recognition. In Experiment 1, Spanish–English bilinguals viewed a series of printed words while making dual-choice go/nogo and left/right hand decisions based on semantic (whether the word referred to an animal or an object) and language membership information (whether the word was in English or in Spanish). Experiment 2 used a similar paradigm but with syntactic information (whether the word was a noun or a verb) as one of the response contingencies. The onset and peak latency of the N200, a component related to response inhibition, indicated that language information is accessed earlier than semantic information. Similarly, language information was also accessed earlier than syntactic information (but only based on peak latency). We discuss these findings with respect to models of bilingual word recognition and language comprehension in general.

1. Introduction

In bilingual communities, it is common to hear individuals mix together more than one language in a single conversation. Even in a single sentence, some words in one language are often substituted with words from another language, forming sentences that laypeople dub “Spanglish” or “Chinglish,” for example. Although it is too simplistic to view language mixing as a sort of hybrid language, the astounding capacity of bilinguals to speak and understand each of their languages with ease poses a central theoretical problem to both cognitive and computational models of bilingual language processing. How do bilinguals manage to separate their two languages when communicating in a monolingual environment, yet also retain the ability to integrate them during language mixing in bilingual conversations? Bilinguals know which of their two languages a given word belongs to, but a central question in the study of bilingual language processing is focused on when a word's language membership first becomes available to the language user, particularly in relation to other linguistic features such as phonology, semantics, and syntax.

Psycholinguists interested in the time course of language processing have examined (in monolinguals) when different kinds of knowledge about words are accessed in real time. In language production, the process of translating an abstract idea into a meaningful utterance is thought to involve at least three levels of representation: semantic (meaning), syntactic (grammatical), and phonological (sound). Models of language production have suggested that in order to produce a word, individuals must first retrieve that word's semantic and syntactic properties before its phonological form can be strung together for articulation (e.g., Levelt, 2001).

Electrophysiological studies of language production have supported this notion of sequential ordering of operations in translating thought to language. Taking advantage of the high temporal resolution of event-related potentials (ERPs), Schmitt et al. (2000) used a dual-choice go/nogo task to determine whether semantic or phonological information is accessed first during implicit picture naming. One type of information (e.g., semantic) determined which hand participants had to use to respond (left or right) while the other type of information (e.g., phonological) was used to determine whether they needed to respond or not (go or nogo). Schmitt et al. reasoned that the implicit naming of pictures engages the same processes that occur naturally when a speaker puts an abstract idea into words and could therefore serve as a proxy

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for the normal process of language production. They focused their analyses on the N200, a negative ERP component proposed to reflect neural activity involved in response inhibition (Jodo and Kayama, 1992; Lavric et al., 2004). In particular, when a participant is asked to respond to one class of stimuli (go trials) and to withhold responding to another class of stimuli (nogo trials), the ERPs recorded on nogo trials contain a larger frontal negativity relative to those recorded on go trials starting at around 200 milliseconds (ms) post-stimulus. Since an individual uses information about the stimulus to determine whether or not to respond, the presence of an N200 implies that such information must have been available for decision-making. Thus, the onset and peak latency of the N200 can be used as an upper estimate of the time at which the task-relevant (go/nogo) information must have been encoded. By making the go/nogo decision dependent on phonological information in half of the trials, and on semantic information in the other half, Schmitt et al. (2000) were able to compare the relative latency of the N200 to determine the time course of semantic and phonological access during language production. In line with most models of language production, they showed that semantic information is available before phonological information (see also Rodriguez-Fornells et al. (2002b)). Other studies using similar methods have shown that, during production, semantic encoding precedes syntactic encoding (Schmitt et al., 2001b), which in turn precedes phonological processing (van Turennout et al., 1998).

Language comprehension is thought to involve similar levels of representation, but the time course of processing stages is not simply the reverse of that in language production. For example, electrophysiological studies have suggested that phonological information is accessed first when individuals hear a word, but before this process is complete, the word's semantic information becomes available (Rodriguez-Fornells et al., 2002b). In turn, access to meaning precedes access to syntactic information when listening (Schmitt et al., 2001a) and when reading (Müller and Hagoort, 2006, though see Neville et al. (1991)).

Most of the studies to date, however, have focused solely on monolinguals. In order to operate successfully in monolingual and mixed-language environments, bilinguals need some way to monitor the appropriate language to use at a given time. The existence of "language tags" has been proposed to address this issue in models of bilingual language production (Green, 1998) and comprehension (Dijkstra and van Heuven, 2002, but see Li and Farkas (2002)). These language tags provide information about which language a particular word belongs to in the bilingual's mental lexicon and could account for bilinguals' ability to restrict their use of vocabulary to one language during conversation. Green's (1998) Inhibitory Control model suggests that these language tags act as a filter during production by inhibiting activation of lemmas with a language tag other than the intended one. Dijkstra and van Heuven (2002), however, argue that the same inhibitory role does not hold during language comprehension. In their revised Bilingual Interactive Activation (BIA+) model of visual word recognition, they propose that language information (carried by language nodes) becomes available too late to restrict the word activation process. Instead, it is the similarity of the visual input to the internal orthographic representations, and not the word's language membership, that determines activation. In other words, this model suggests that language nodes lack a functional role within the word identification system.

The idea that language information may not be playing a functional role in the word identification system is supported by studies showing cross-lingual activation even when context or task demands could have allowed for selective access (e.g., Canseco-Gonzalez et al., 2010; Dijkstra et al., 2000; Duyck et al., 2007). Dijkstra et al. (2000), for example, found that participants were slower at recognizing interlingual homographs (e.g., the English word *room* which means *cream* in Dutch) as words in the target language (e.g., Dutch) if the homographs had a high frequency in the non-target language (e.g., English). To optimize performance in this task, it would have been advantageous to completely ignore the non-target language. However, the slowed reaction times suggest that recognition of the homograph from the non-target language somehow interfered with recognition of the target language reading. This suggests that access to the language information occurred too late to aid in the lexical selection process. On the other hand, Rodriguez-Fornells et al. (2002a) found that language information could in fact be used to suppress both phonological and, to some extent, semantic processing of words in the non-target language during word recognition.

Given the experimental evidence supporting both language selective and non-selective lexical access (see Dijksta, 2005, for a review), a central question is when, in relation to other levels of language processing, bilingual speakers identify a particular word as belonging to a particular language. To better delineate the time course of access to different types of information during bilingual language processing, we conducted two experiments to examine when language information is accessed relative to semantic information (Experiment 1) and syntactic information (Experiment 2) in comprehension. In line with observations that semantic and syntactic representations in the target language can activate or be primed by those in the non-target language (Desmet and Declercq, 2006; Kantola and van Gompel, 2011; Martin et al., 2009; Schoonbaert et al., 2007; Thierry and Wu, 2007), we may expect that bilingual speakers will access a word's semantic and syntactic information before they access its language information. Alternatively, the temporal ordering of language membership, semantic, and syntactic information may not follow a consistent order and may instead be modulated by the global activation of the two languages in which participants are tested (Ng and Wicha, 2013).

Following the setup of previous studies (e.g., Schmitt et al., 2000), we pitted language information directly against semantic information in Experiment 1, and against syntactic information in Experiment 2, in a dual-choice go/nogo task using printed words. We chose to use the written word form because all perceptual information is provided at once, as opposed to the spoken word form, which is extended in time (Zorzi, 2000). By making the go/nogo decision dependent on language information in half of the conditions and on semantic (or syntactic) information in the other half, we were able to compare the relative latency of the inhibition-related N200 effect to determine the temporal course of language information processing relative to semantic and syntactic encoding during visual word recognition in bilinguals.

2. Experiment 1

2.1. Methods

2.1.1. Participants

Twenty individuals proficient in both Spanish and English (nine females, with a mean age of 22.6 years; range: 18–29) were paid to participate in the experiment. All individuals were neurologically intact and had normal or corrected-to-normal vision. Average age of first exposure to Spanish was 3.95 years (range: 0–27)[1] and to English 3.65 years (range: 0–7). Age of acquisition did not differ between the two languages, $t(19)=0.15$, $p=.88$. To be included in

[1] The one individual who reported this late age of acquisition had scored above the mean in our objective measures of both English and Spanish. Importantly, excluding this individual in our analyses did not affect the overall pattern of results and this data was therefore maintained.

the study, all participants had to report high English and Spanish proficiency, measured via the Language Experience and Proficiency Questionnaire (LEAP-Q; Marian et al., 2007). The average self-report scores of Spanish/English speaking, understanding, and reading proficiency (with 10 being the highest) were 8.50/9.05, 9.10/9.55, and 8.05/9.15, respectively. Although their reported proficiency levels were comparable across the two languages, participants reported more frequent use of English on average (73% of the time vs. 27% of the time in Spanish, $t(19) = -7.98$, $p < 0.001$), which we believe to be a result of our bilingual sample living and studying in a predominantly English environment.

To obtain a more objective assessment of proficiency levels, the Peabody Picture Vocabulary Test Third Edition was administered to all participants in both English and Spanish. In this test, subjects heard recordings of a set of words (made by native speakers of each language) and selected the picture that best matched each word. Different sets of pictures were used across the two tests. Order of presentation was counterbalanced across subjects, with half receiving the English version first and the other half receiving the Spanish version first. Raw scores were converted into a standard score, with 160 as the highest possible score. The average standard score for the English version was 106.15 ($SD = 8.35$), and the average standard score for the Spanish version was 107.60 ($SD = 7.48$). A paired samples *t*-test indicated that there was no difference between the standard scores, $t(19) = -0.75$, $p = .47$, suggesting that performance on this objective assessment was equivalent across languages.

2.1.2. Stimuli

The stimuli were 160 words divided into two semantic categories: 80 animals and 80 objects. Of these two categories, half of the words were in English and half were in Spanish. Twenty additional words (five in each category) were used during the practice trials. Word length was matched across the four different categories. Log word frequency was matched for the English and Spanish words using the SUBTLEX-US (Brysbaert and New, 2009) and SUBTLEX-ESP (Cuetos et al., 2011) databases, respectively ($p = 0.26$). Nevertheless, Spanish words had a higher initial bigram frequency than English words (Davis, 2005; Duchon et al., 2013), $p < 0.001$. Since language-specific orthographic cues can enable participants to recognize words more quickly in a particular language (e.g., Grainger and Beauvillain, 1987), all words were presented in capital letters to avoid the use of diacritical markers, which are only present in Spanish. To further ensure that we were not favoring one language over the other, we made sure that any disambiguating information about whether the word was in English or in Spanish could not occur until at least the fourth letter. We also avoided bigrams that are uncommon or absent in one of the languages at the beginning of the word (e.g., ‘wh’ is common in English but is never present in Spanish). A pretest using our stimulus list indicated that the time to make a language decision by itself (i.e., “is the word in English or in Spanish?”; $M = 716.12$ ms, $SD = 61.99$) was comparable to the time to make a semantic decision by itself (i.e., “is the word an animal or an object?”; $M = 702.43$ ms, $SD = 69.61$), $t(6) = 0.23$, $p = 0.65$. There was also no difference in the mean proportion of correct responses (language decision: $M = 0.94$, $SD = 0.07$, semantic decision: $M = 0.96$, $SD = 0.05$), $t(6) = 1.20$, $p = 0.27$, indicating that the level of difficulty was comparable across the two types of decisions. The complete list of stimuli can be found in Appendix A.

2.1.3. Design

The design was adapted from the dual-choice go/nogo paradigm used by Schmitt et al. (2000), where one type of linguistic information determined the hand with which to respond (left or right), and another determined whether or not to make a response (go or nogo). There were eight different instruction sets in total. In four of the instruction sets, the responding hand was contingent on semantic information (e.g., respond with the left hand if the word is an animal and the right hand if the word is an object) and the go/nogo decision was contingent on language information (e.g., respond only if the word is in English but not if the word is in Spanish). In the other four instruction sets, the contingencies were reversed. Table 1 illustrates the eight different instruction sets. Left- and right-hand and go and nogo responses were counterbalanced across participants, such that each participant received only four of the eight conditions (i.e., odd- or even-numbered conditions in Table 1). Half of the participants performed the go/nogo=semantic conditions first and the other half the go/nogo=language conditions first. The order of conditions was randomized across participants.

2.1.4. Procedure

Before the ERP study, participants were familiarized with the stimuli. They were shown a list of all the target words and asked to indicate whether the word was in English or Spanish and whether the word was an animal or an object. If participants made mistakes on fewer than five words per category, they were trained with the words they did not know (typically about two or three English and/or Spanish animal names). Participants who made more than five errors in a given category were excluded from participation.

Participants were seated in a dimly lit soundproof chamber facing a computer screen located 80 cm from their eyes. Words were presented on the center of the screen for 1500 ms or until participants made a response, whichever occurred earlier. Each word was separated by a fixation cross with a random inter-stimulus interval (ISI) between 1300 and 1700 ms. Words were presented in white uppercase letters against a black background in

Table 1
Eight instruction sets. Participants were either assigned the odd- or even-numbered instructions.

Condition	Instruction
Go/nogo=language	1. Press the left button if the word is an animal. Press the right button if it is an object. Respond only if it is in English.
	2. Press the left button if the word is an object. Press the right button if it is an animal. Respond only if it is in English.
	3. Press the left button if the word is an animal. Press the right button if it is an object. Respond only if it is in Spanish.
	4. Press the left button if the word is an object. Press the right button if it is an animal. Respond only if it is in Spanish.
Go/nogo=semantics	5. Press the left button if the word is in English. Press the right button if it is in Spanish. Respond only if it is an animal.
	6. Press the left button if the word is in Spanish. Press the right button if it is in English. Respond only if it is an animal.
	7. Press the left button if the word is in English. Press the right button if it is in Spanish. Respond only if it is an object.
	8. Press the left button if the word is in Spanish. Press the right button if it is in English. Respond only if it is a object.

36 pt Times New Roman font, at a visual angle of 1.4–4.3° depending on their length.

Each condition began with 20 practice trials. Participants were told to respond as quickly and as accurately as possible. Following the practice trials, the 160 words were presented individually in four experimental blocks of 40 words each. There was a short break between blocks. All words were randomized across the experimental blocks. Participants saw all 160 words in each condition, and therefore each stimulus was presented to each participant four times (i.e., once per condition). Each condition lasted about 10 min for a total session of 40 min plus breaks.

2.1.5. Apparatus and recording

The EEG was recorded from the scalp using Ag/AgCl electrodes mounted in an elastic cap and at 28 standard positions: Fp1/2, AF3/4, F7/8, F3/4, FC5/6, FC1/2, C3/4, CP1/2, P3/4, PO3/4, PO7/8, O1/2, Fz, Cz, Pz, and Oz (EASYCAP, Herrsching, Germany). Electrical potentials were referenced online to the left mastoid and re-referenced offline to the average of the left and right mastoids. Additional electrodes were placed on the outer side of the left and right eyes to record horizontal eye movements and beneath the left eye to record vertical eye movements and blinks. The EEG was amplified, bandpass filtered at 0.1–150 Hz, and digitized at a rate of 500 Hz (BrainAmp Standard, Brain Products, Gilching, Germany). Trials containing blinks, eye movements, or muscle artifacts were detected and rejected using a semi-automatic procedure (peak-to-peak amplitude thresholds were adjusted per individual subject). Only artifact-free and correct-response/non-response trials were entered into the analysis. On average, the percentage of artifact-free and correct response/nonresponse trials contributing to individual ERPs in each of the four conditions were: GO Language = 77.1%, NOGO Language = 78.7%, GO Semantics = 72.1%, NOGO Semantics = 79.2%.

2.2. Results

2.2.1. Behavioral results

Incorrect responses (i.e., responding with the wrong hand or during a nogo trial) and responses longer than 1500 ms were excluded from the reaction time analysis. The error proportion for the go/nogo = language condition (M = 12.63%, SD = 8.04) did not differ from the error proportion for the go/nogo = semantics condition (M = 14.79%, SD = 11.53) according to a paired samples t-test, $t(19) = 1.36$, $p = .19$. The mean reaction time for correct go responses was 896.96 ms (SD = 88.52) for the go/nogo = language condition and 893.18 ms (SD = 93.46) for the go/nogo = semantics condition. There was no significant difference in reaction time between the two conditions, $t(19) = 0.23$, $p = .82$.

Accuracy was measured using the statistic d-prime (d'), which takes response bias into account by weighting the proportion of false alarms (i.e., responding on a nogo trial) against the proportion of correct responses (i.e., responding on a go trial). The higher the d' score, the better the subject was at maximizing the number of hits and minimizing the number of false alarms. Subjects had a higher d' score in the go/nogo = language condition (M = 3.69, SD = 1.19) compared to the go/nogo = semantics condition (M = 3.37, SD = 1.08), $t(19) = 2.39$, $p = .03$, suggesting that they were more likely to correctly press the button during a go trial and withhold their responses during nogo trials when language information determined whether or not to respond. As the proportion of incorrect responses did not differ between conditions, this d' difference is likely due to a higher false alarm rate in the go/nogo = semantics condition (3.35%) versus the go/nogo = language condition (2.23%).

2.2.2. N200 analysis

We computed individual and grand average ERPs for the go and nogo trials for both the go/nogo = semantics and go/nogo = language conditions. ERPs were time-locked to the onset of the word presentation, re-referenced to the average of the left and right

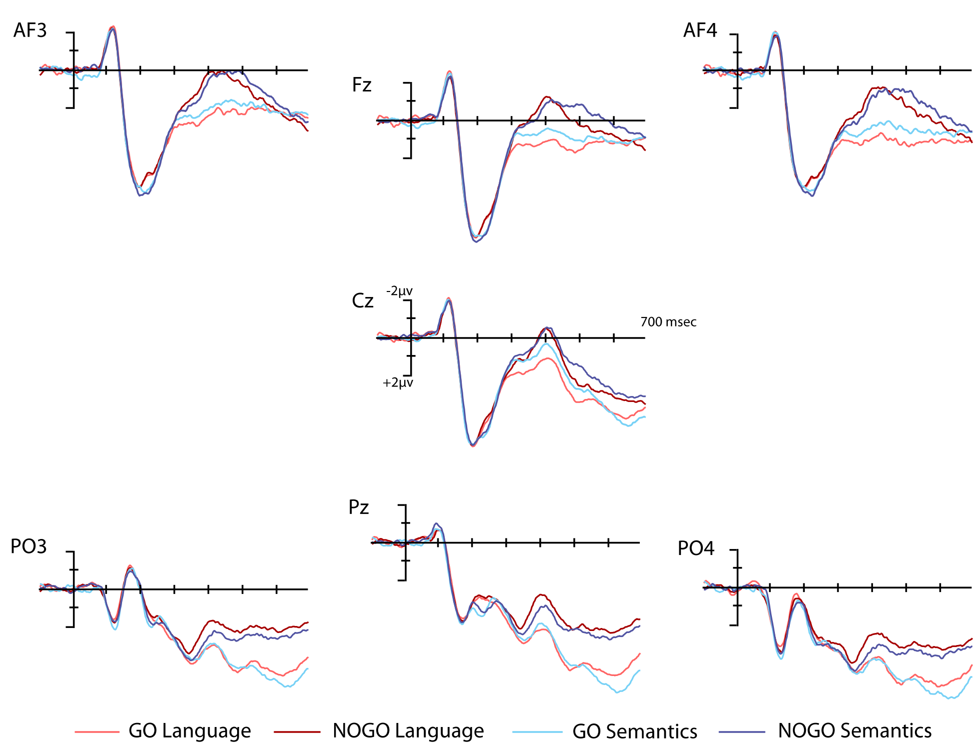

Fig. 1. Superimposed grand average ERPs for all four conditions in 7 representative electrodes.

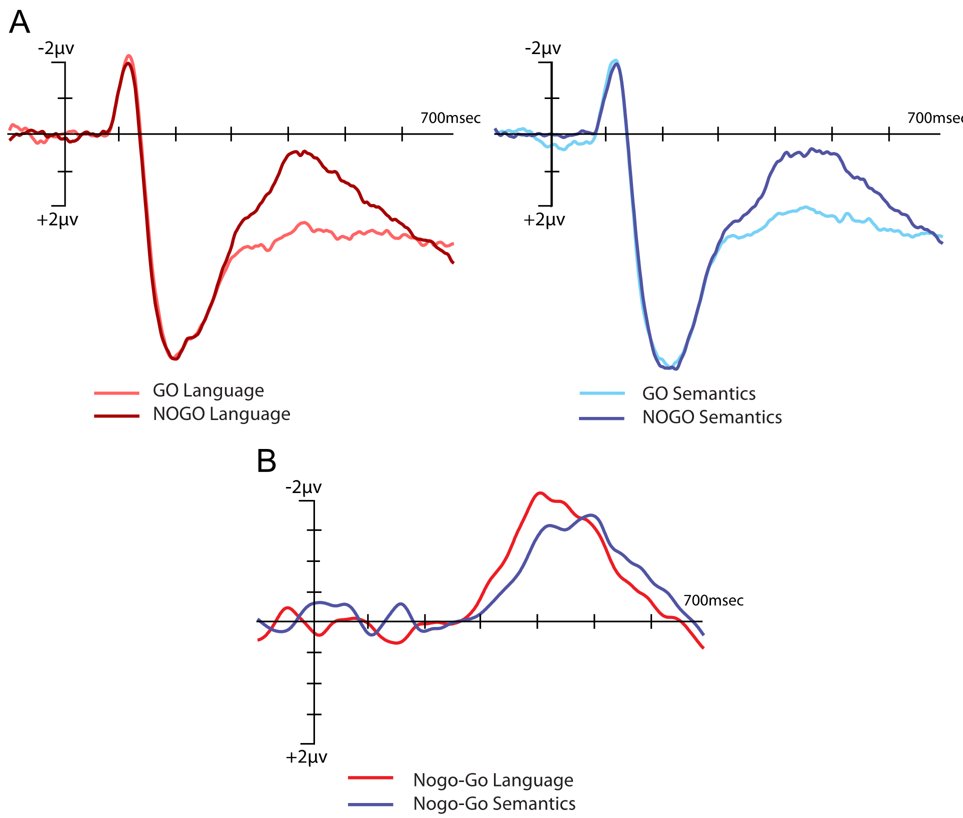

Fig. 2. (A) Grand average ERPs in the go/nogo=language condition (left) and the go/nogo=semantics condition (right) pooled across nine frontal electrodes. (B) Superimposed difference waves for the two conditions (This and future difference waves plots were low-pass filtered at 15 Hz, 24 db/octave for display purposes only).

mastoids, and baseline corrected from −100 to 0 ms. Before analysis ERPs were low-pass filtered at 30 Hz, 12 db/octave and a 60 Hz notch filter was applied to get rid of high frequency noise introduced by a piece of equipment. Fig. 1 shows grand average ERPs to each of the four experimental conditions in several representative electrodes across the scalp. To isolate the two N200 effects, we subtracted the go waveforms from the nogo waveforms separately for each condition to create difference waves. As expected, both response contingency conditions showed a clear N200 effect, with nogo trials eliciting a larger negativity than go trials. Since the N200 effect had a typical frontal distribution, we focused our analyses on the nine frontal electrodes (Fp1/2, AF3/4, F7/8, F3/4, and Fz). Fig. 2 presents average ERPs (on top) and corresponding difference waves (on bottom) for each condition collapsed across the nine frontal electrodes.

We assumed that the increased negativity for nogo trials is a reflection of the time when enough information becomes available to withhold a response. We therefore studied the temporal characteristics of the N200 effects for each response contingency via two separate latency measures to get an upper estimate of when semantic and language information were accessed. Onset and peak latency and peak and mean amplitude values for the two N200 effects were analyzed using linear mixed effects models and the lme4 package in R (Bates, 2007). Condition (go/nogo=language vs. go/nogo=semantics) was contrast coded and included as a fixed effect.[2] By-subject random slopes for condition and random intercepts for subjects were included in the random effects structure for all models. Latency and amplitude values for each electrode site can be found in Appendix C. Parameter estimates for all models are included in the Supplementary materials.

2.2.2.1. Onset latencies. The onset latency of the N200 component reflects the moment in time when go and nogo trial ERPs first diverge from each other. Onset latency was calculated for each individual difference waveform at each of the nine frontal electrode sites using a fractional peak latency analysis, defined as the point at which the difference waveform reached 30% of its peak amplitude. Following Luck's (2014) advice on how to analyze onset latencies, 30% of the peak amplitude was chosen as our relative criterion after we determined when, on average, the go and nogo waveforms started deviating significantly from each other. This was analyzed by carrying out a series of consecutive paired samples t-tests on the mean amplitudes of the go and nogo waveforms. Starting from 100 ms after word onset, mean amplitudes were averaged across consecutive 40-ms windows (i.e., ±20 ms relative to each measurement point) every four ms for the go and nogo waveforms separately. In other words, the first window was from 100 to 140 ms, the second window was from 104 to 144 ms, and so on. Significant divergence between the go and nogo waveforms was defined as the point at which four consecutive t-tests showed a significant difference between the mean amplitudes of the two waveforms. We identified a significant difference in amplitude for each electrode site between the go-nogo responses (x). We also found the peak amplitude of the corresponding grand-average difference waves (y). We then calculated the percentage of the peak amplitude (y) that the significant difference (x) made up by dividing x by y. Averaged across conditions and electrode sites, this calculation was equal to 30% of the peak amplitude. It was therefore chosen as our relative criterion for our fractional peak latency analysis.

[2] An initial model that included hemisphere as a fixed effect indicated larger peak amplitudes in the right hemisphere than in the left (Estimate: −0.41 µV, Standard error: 0.14 µV, $t=-2.88$, $p=.007$) but suggested no hemispheric differences for either of the latency measures. As this did not interact with our condition variable, we collapsed our analyses across left and right hemisphere electrodes.

Latencies are reported with values averaged across the nine frontal electrodes. The mean onset latency for the N200 when go/nogo=language was 308 ms (SD=58.50). The mean onset latency for the N200 when go/nogo=semantics was 333 ms (SD=63.62). This 25-ms difference in onset latency was marginally significant (Estimate: 25.33 ms, Standard error: 13.44 ms, t=1.88, p=0.06).

2.2.2.2. Peak latencies. Peak latency was defined as the time at which each individual difference waveform reached its most negative voltage. For each participant, the peak latency of the N200 effect was measured between 200 and 600 ms at each frontal electrode for the two conditions separately. Similar to the relative difference in onset latency, the N200 effect peaked significantly earlier for the go/nogo=language condition than for the go/nogo=semantics condition (Estimate: 32.34 ms, Standard error: 16.85 ms. t=1.92, p=.05). The N200 effect peaked around 442 ms (SD=66.81) for the go/nogo=language condition and around 475 ms (SD=72.38) for the go/nogo=semantics condition.

2.2.2.3. Peak amplitudes. Peak amplitude was defined as the most negative voltage each individual difference waveform reached between 200 and 600 ms. Amplitudes were measured at each frontal electrode for the two conditions separately for each participant. The mean peak amplitude across the frontal electrodes was −3.65 μV (SD=1.94) for the go/nogo=language condition and −3.30 μV (SD=1.39) for the go/nogo=semantics condition. There was no significant difference in peak amplitude across these two response contingencies (Estimate: 0.35 μV, Standard error: 0.36 μV, t=0.97, p=.33).

2.2.2.4. Mean amplitudes. Mean amplitudes were measured between 200 and 600 ms at each frontal electrode for the two conditions separately for each participant. There was no significant difference in mean amplitude between the go/nogo=language condition (M=−1.06 μV, SD=1.11 μV) and the go/nogo=semantics condition (M=−0.86 μV, SD=0.99 μV) across the frontal electrodes (Estimate: 0.21 μV, Standard error: 0.24 μV, t=0.85, p=0.39).

2.2.2.5. Interim summary. In summary, these results suggest earlier access to language than semantic information (by ~25–30 ms) as evidenced by an earlier onset and peak latency of the N200 component. Two questions emerged from these initial findings. First, because we found a higher false alarm rate when participants relied on semantic information to decide whether to withhold their response or not, it is possible that the language advantage we found is simply due to a difference in task difficulty. We address this possibility in the discussion.

Second, although our participants reported being fluent in both languages, and objective vocabulary measures were comparable across languages, as a group they reported using English more regularly. Therefore, our N200 latency results may have been disproportionately driven by a language bias that was obscured by combining the data across the two language conditions. The following analysis investigates this possibility in detail.

2.2.3. English vs. Spanish

Given recent results that suggest the temporal ordering of access to semantic and language information differs depending on which language serves as the target (Ng and Wicha, 2013), we decided to split our analyses between English and Spanish words to see whether a similar temporal re-ordering occurred in our experiment. We refer to this variable as “trial type” (i.e., participants were tested with either an English word or a Spanish word in each trial). Splitting the data by trial type resulted in four different combinations of condition by trial type: go/nogo=language with English words, go/nogo=language with Spanish words, go/nogo=semantics with English words, and go/nogo=semantics with Spanish words.

2.2.3.1. Behavioral results by trial type. Reaction times were submitted to a 2 (condition: go/nogo=language versus semantics) × 2 (trial type: English versus Spanish words) × 2 (semantic category: animal versus object) repeated measures ANOVA. Semantic category was included to examine the contingency that determines handedness. Handedness was also included as a between-subjects factor to ensure that effects did not differ depending on which hand was assigned to respond to which stimulus category. There was a significant condition by trial type interaction, F(1,18)=5.59, p=0.03. Although in general participants tended to respond faster to English words, the difference in reaction time between the two languages was much more pronounced in the go/nogo=semantics condition (55 ms; SD=23.47) compared to the go/nogo=language condition (4 ms; SD=17.70). There was, however, no condition difference within trial type, suggesting that reaction times were comparable between the two response contingencies irrespective of the language of the stimuli. Participants were also slower to respond to objects (M=912.41 ms, SD=107.02) than animals (M=865.16 ms, SD=146.70), F(1,18)=12.78, p=0.002, though this effect of semantic category did not interact with trial type, F(1,18)=0.37, p=0.55. The slower reaction time to objects was more pronounced when semantic information was determining the go/nogo response (81 ms difference) than when it was determined by language information (13 ms difference), leading to a semantic category by condition interaction, F(1,18)=6.06, p=0.02. This suggests that it took participants longer to map objects onto response hand for both trial types than to map the language membership of those same objects onto response hand. There was no main effect of handedness, nor did it interact with any of the three variables, suggesting that similar effects were observed regardless of which stimulus category was mapped to which hand.

Participants had lower d' scores when responding to words in Spanish (M=3.12, SD=1.24) than when responding to words in English (M=3.95, SD=1.32), F(1,19)=16.50, $p < 0.001$, regardless of which type of information was determining the go/nogo response. In other words, participants were more likely to correctly respond to a go trial and withhold their response to a nogo trial when the word they read was in English compared to when it was in Spanish. However, although there was also a main effect of condition, F(1,19)=5.74, p=0.03, there was no trial type by condition interaction, suggesting that participants were better at

Table 2
Reaction times and d' scores for each condition split by trial type. Standard deviations are in parentheses.

English words			Spanish words	
Condition	Reaction time (ms)	*d*-Prime	Reaction time (ms)	*d*-Prime
Go/nogo=language	895.07 (88.69)	4.03 (1.27)	898.85 (106.39)	3.35 (1.25)
Go/nogo=semantics	865.54 (91.50)	3.86 (1.40)	920.82 (114.97)	2.89 (1.22)
Average	880.31 (90.19)	3.95 (1.32)	909.84 (109.90)	3.12 (1.24)

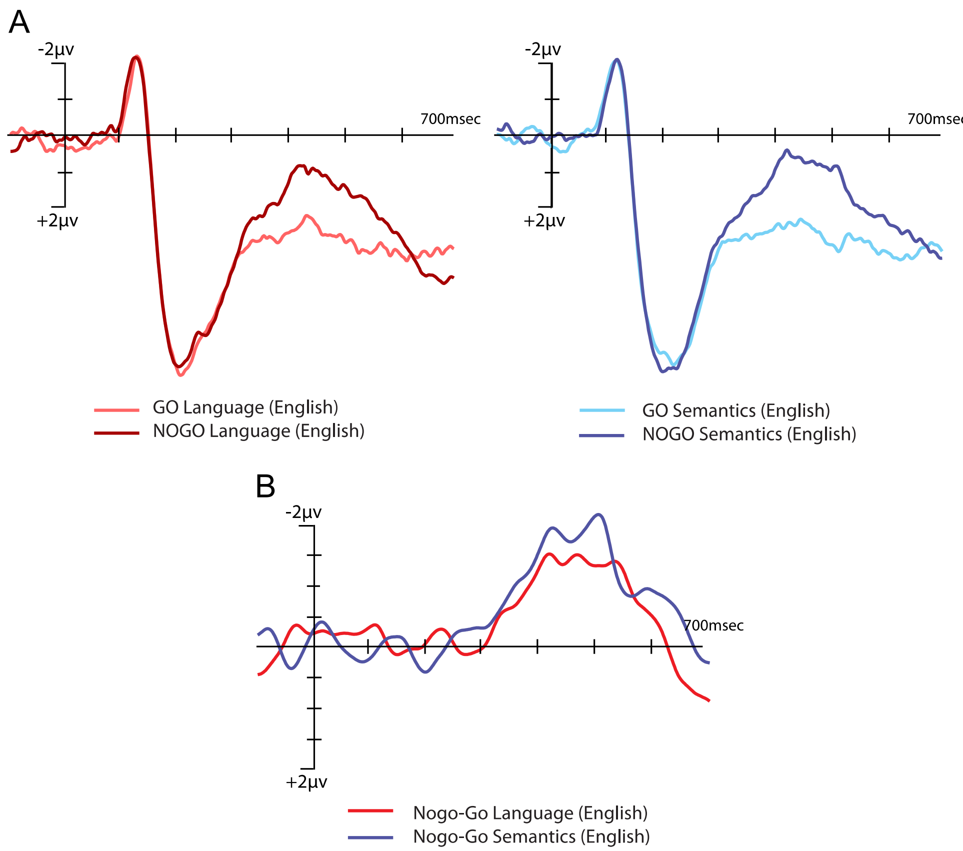

Fig. 3. English trials. (A) Grand average ERPs in the go/nogo=language condition (left) and the go/nogo=semantics condition (right) pooled across nine frontal electrodes. (B) Superimposed difference waves for the two conditions.

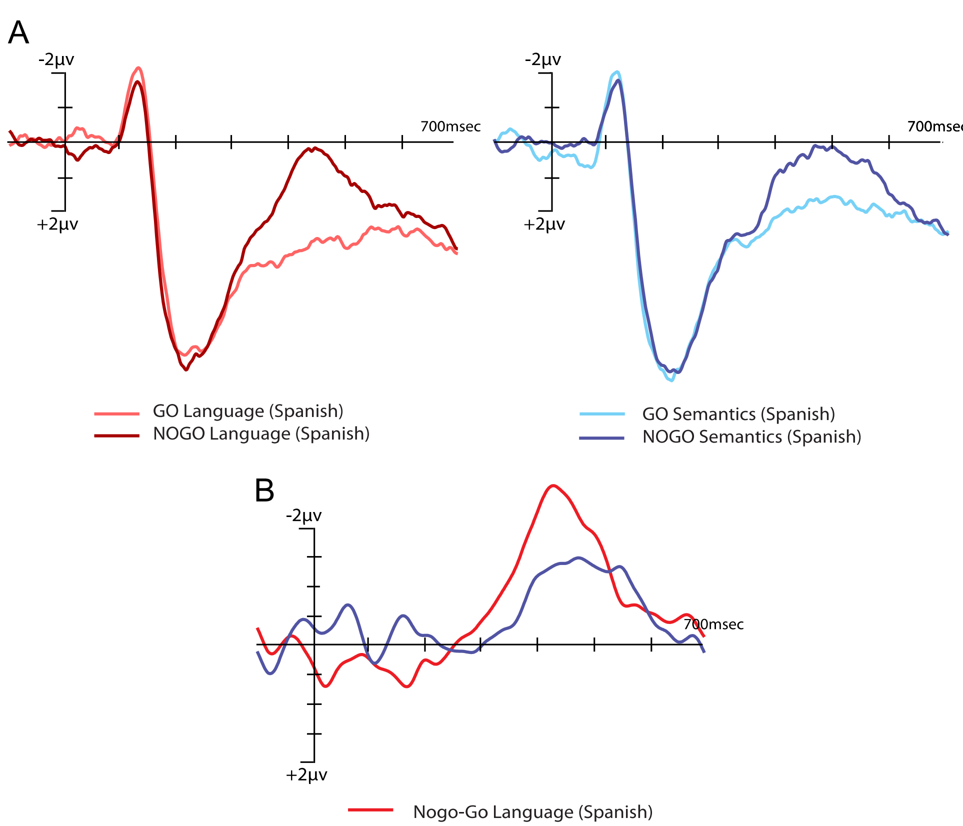

Fig. 4. Spanish trials. (A) Grand average ERPs in the go/nogo=language condition (left) and the go/nogo=semantics condition (right) pooled across nine frontal electrodes. (B) Superimposed difference waves for the two conditions.

maximizing hits and minimizing false alarms in the go/nogo=language condition irrespective of which language the words were presented in. Table 2 lists the behavioral results for the two conditions split by trial type.

2.2.3.2. N200 analysis by trial type. Splitting our analysis by trial type reduced the number of trials that went into each individual and grand-average waveform in half (with a maximum of 80 trials for each condition). On average, the percentage of artifact-free and correct response/nonresponse trials contributing to individual ERPs in each of the eight conditions were as follows. English: GO Language=77.9%, NOGO Language=79.13%, GO Semantics=73.56%, NOGO Semantics=78.75%. Spanish: GO Language=76.88%, NOGO Language=81.25%, GO Semantics=69.5%, NOGO Semantics=77.56%.

Due to the reduced signal-to-noise ratio, these findings need to be considered with caution. However, it was clear that both response contingencies still elicited a clear N200 effect in each language. We focused again on the same nine frontal electrode sites for our analyses. Grand average ERPs and corresponding difference waves (collapsed across the nine frontal electrodes) can be seen for each condition in English trials in Fig. 3 and in Spanish trials in Fig. 4.

Trial type was contrast coded and added as a fixed effect in our original model and by-participant random slopes for trial type were added to the random effects structure. Average latency measures split by trial type for each electrode are listed in Appendix D. Table 3 lists the average onset and peak latencies and peak and mean amplitude averages for each condition split by trial type.

2.2.3.3. Onset latencies by trial type. Onset latencies were again defined as the point at which the difference waveform reached 30% of its peak amplitude. There was neither a main effect of trial type (Estimate: 4.24 ms, Standard error: 11.76 ms, $t=0.36$, $p=.73$) nor a condition by trial type interaction (Estimate: 30.59 ms, Standard error: 31.46, $t=0.97$, $p=.33$), suggesting that language membership information was accessed prior to semantic information for both trial types. Note that this finding is in contrast to Ng and Wicha's (2013) findings suggesting that, when responding to Spanish target words, access to meaning occurred earlier than language information. If anything, the current data showed a trend in the opposite direction: access to language information slightly preceded access to semantic information for Spanish words (see difference waves in Fig. 4), and this difference is even numerically more pronounced than that observed in English trials. We return to this point in the discussion.

2.2.3.4. Peak latencies by trial type. As with onset latency, neither trial type nor a trial type by condition interaction were significant predictors in the model for peak latency, suggesting that the N200 reached its peak for both English and Spanish words earlier when language information was determining the go/nogo response compared to when semantics was the determiner.

2.2.3.5. Peak and mean amplitudes by trial type. There was no main effect of trial type for either amplitude measure. Although the peak and mean amplitudes were numerically greater in the go/nogo=language condition than in the go/nogo=semantics condition for Spanish words while the opposite was observed for English words, the condition by trial type interaction for the two amplitude measures did not reach significance (peak – Estimate: 1.19 μV, Standard error: 0.76 μV, $t=1.57$, $p=.12$; mean – Estimate: 0.55 μV, Standard error: 0.76 μV, $t=0.73$, $p=.47$).

2.3. Discussion

Experiment 1 took advantage of the high temporal resolution of ERPs to investigate the relative timing of access to semantic and language information during visual word recognition. We used both the onset and peak latencies of the N200, a component related to response inhibition, as an upper estimate of when semantic and language information were available for decision-making. The mean onset latency of the N200 occurred approximately 25–30 ms earlier when the go/nogo response was contingent on language information than when it was contingent on semantic information. Mean peak latency showed a similar temporal ordering. This suggests that when these two types of information are pitted directly against each other, bilinguals access information about a word's language membership before they access information about its meaning. Although our participants made significantly more false alarms in the semantic task, there were no differences in reaction time. Furthermore, when we pretested each task and each language separately, we found no differences in task difficulty nor in reaction time. Therefore, it seems that the particular advantage for language information appears when our participants are confronted with the two tasks simultaneously.

Importantly, this temporal pattern of accessing language information before semantics persisted regardless of which language participants were tested in. This particular finding is somewhat contrary to that of Ng and Wicha (2013), who found an advantage for semantic information when using Spanish words as targets (when they used English words as targets, our results were similar). The authors suggest that the order in which meaning and language membership is accessed may be based on how frequently a particular language is used. Specifically, they argue that the more frequently a language is used, the faster the words are identified as belonging to that particular language. Since their participants were living in and tested in an environment where English was the predominant language, their level of Spanish activation may not have been high enough to cause interference when English was the target language or to inhibit words in the non-target language when told to respond only to Spanish words. Although our reaction time measures and d' scores suggest that our participants may have had a slightly harder time with the semantics condition in Spanish, this difference in task difficulty was not reflected in our ERP latency measures. Furthermore, similarly to Ng and Wicha's study, our bilingual sample as a group can also be classified as more English-dominant. We address possible reasons for the apparent conflict between our findings and those of Ng and Wicha in the general discussion.

Table 3
Mean latencies and amplitudes for the N200 waveforms split by trial type averaged across the nine frontal electrode sites. Standard deviations are in parentheses.

	English words				Spanish words			
Condition	Onset latency (ms)	Peak latency (ms)	Peak amplitude (μV)	Mean amplitude (μV)	Onset latency (ms)	Peak latency (ms)	Peak amplitude (μV)	Mean amplitude (μV)
Go/nogo=language	312.72 (81.40)	446.63 (79.87)	−4.16 (2.21)	−0.79 (1.79)	301.83 (67.78)	445.41 (74.05)	−5.03 (2.74)	−1.14 (2.13)
Go/nogo=semantics	321.53 (70.93)	480.40 (83.78)	−4.45 (1.81)	−1.01 (1.47)	340.34 (62.77)	460.35 (90.71)	−3.90 (1.83)	−0.72 (1.38)

3. Experiment 2

Time course studies on monolingual language comprehension suggest that semantic information becomes available prior to syntactic information when listening to (Schmitt et al., 2001a) and when reading words (Müller and Hagoort, 2006; Wong and Chen, 2012). Given our findings with bilinguals in Experiment 1 suggesting that access to language information appears to precede access to semantic information, it is reasonable to expect that language information would also become available before syntactic information. Experiment 2 aims to test this prediction by directly pitting these two types of information against each other in a similar dual-choice go/nogo task.

3.1. Methods

3.1.1. Participants

Twenty-five individuals (14 females, mean age: 20.92, range: 18–29) proficient in both English and Spanish were paid to participate in the experiment (none of these individuals participated in Experiment 1). All individuals were neurologically intact and had normal or corrected-to-normal vision. Average age of exposure to Spanish was 4.36 years (range: 0–19) and 3.76 years (range: 0–10) to English. Age of acquisition did not differ between the two languages, $t(24)=0.43$, $p=0.67$. As in Experiment 1, all participants had to report high English and Spanish proficiency on the LEAP-Q (Marian et al., 2007). The average self-report scores of Spanish/English speaking, understanding, and reading proficiency (with 10 being the highest) were 8.44/9.08, 9.04/9.56, and 7.84/9.20, respectively. Participants reported using English about 79% of the time while using Spanish about 21% of the time, $t(24)=-7.71$, $p<0.001$. Again, we believe this more frequent use of English is likely a result of participants living and studying in a predominantly English environment. The Peabody Picture Vocabulary Test Third Edition was administered in both English and in Spanish (order counterbalanced) to get a more objective measure of participants' Spanish–English language abilities. Standard scores (160 maximum) did not differ across the two languages (English: $M=109.90$, $SD=6.87$; Spanish: $M=109.40$, $SD=8.86$), $t(24)=0.28$, $p=.79$.

3.1.2. Stimuli

The stimuli were 160 words divided into two syntactic categories: 80 nouns and 80 verbs. Of these two categories, half of the words were in English and half were in Spanish. Twenty additional words (five in each category) were used during the practice trials. Word length, word frequency (Brysbaert and New, 2009; Cuetos et al., 2011), and initial bigram frequency (Davis, 2005; Duchon et al., 2013) were matched across the four different categories. All words were presented in capital letters to avoid the use of diacritical markers, which are only present in Spanish. To further ensure that we were not favoring one language over the other, we made sure that any disambiguating information about whether the word was in English or in Spanish could not occur until the fourth letter or later. Letter combinations that are uncommon in one of the languages were avoided at the beginning of the word. To prevent participants from using the strategy of identifying Spanish verbs solely based on their ending (i.e., -ar, -er, -ir), some verbs were presented in their conjugated forms (e.g., *hablas,* "you talk" instead of the infinitive *hablar*, "to talk"). Tense was modified in some of the English verbs (e.g., "described") to make the task more comparable. Participants were familiarized with the stimuli prior to the experimental task. The full list of stimuli including their mean frequencies is provided in Appendix B.

3.1.3. Procedure

We followed the exact same design and procedure as in Experiment 1, only now syntactic information ("is the word a noun or a verb?") replaced semantic information as one of the response contingencies. ERPs were recorded and analyzed with the same settings from the same scalp sites as in Experiment 1.

3.2. Results

3.2.1. Behavioral results

The proportion of errors (incorrect responses and responses over 1500 ms) for the go/nogo=language condition ($M=9.70\%$, $SD=6.71$) did not differ from the error proportion for the go/nogo=syntax condition ($M=8.88\%$, $SD=7.35$) according to a paired samples t-test, $t(24)=0.94$, $p=.36$. However, participants responded significantly faster in the go/nogo=syntax condition than in the go/nogo=language condition, $F(1,23)=5.38$, $p=.03$. The mean reaction times for correct go responses were 880.32 ms ($SD=109.94$) for the go/nogo=language condition and 858.04 ms ($SD=108.08$) for the go/nogo=syntax condition. Taking into consideration which language participants were responding in, we see a significant trial type by condition interaction, $F(1,23)=7.29$, $p=0.01$, revealing that the delay in reaction time for the go/nogo=language condition is likely guided by participants being slower to respond positively to English words. Reaction times for the other three conditions were nearly identical (see Table 4). A similar pattern was observed with syntactic category: While reaction times to nouns were comparable across the two conditions and two trial types (range: 860–884 ms), participants tended to respond slower to English verbs in the go/nogo=language condition ($M=927.13$ ms, $SD=110.19$). This slow-down was not observed in the go/nogo=syntax condition ($M=856.22$ ms, $SD=111.78$), leading to a condition by syntactic category interaction, $F(1,23)=25.08$, $p<0.001$. This suggests that it takes longer to map the syntactic category of verb to the correct response hand than it does to map language membership of the same exact stimuli (English verbs) to the same hand, regardless of whether the response had to be mapped to the left or right hand (i.e., no interaction nor main effect of handedness).

Subjects had a significantly higher d' score in the go/nogo=language condition ($M=3.69$, $SD=0.54$) compared to the go/nogo=syntax condition ($M=3.44$, $SD=0.67$), $F(1,24)=7.63$, $p=0.01$. Since the error proportion did not differ between the two conditions, this d' difference is likely guided by a higher false alarm rate in the go/nogo=syntax condition (3.10%) versus the go/nogo=language condition (1.16%). This pattern occurred regardless of whether participants were responding to English or Spanish

Table 4
Reaction times and d' scores for each condition split by trial type. Standard deviations are in parentheses.

English words			Spanish words	
Condition	Reaction time (ms)	*d*-Prime	Reaction time (ms)	*d*-Prime
Go/nogo=language	901.17 (101.05)	3.65 (0.55)	859.48 (116.45)	3.75 (0.53)
Go/nogo=syntax	857.58 (88.82)	3.34 (0.62)	858.49 (126.32)	3.53 (0.72)
Average	879.37 (96.69)	3.49 (0.60)	858.99 (120.24)	3.64 (0.63)

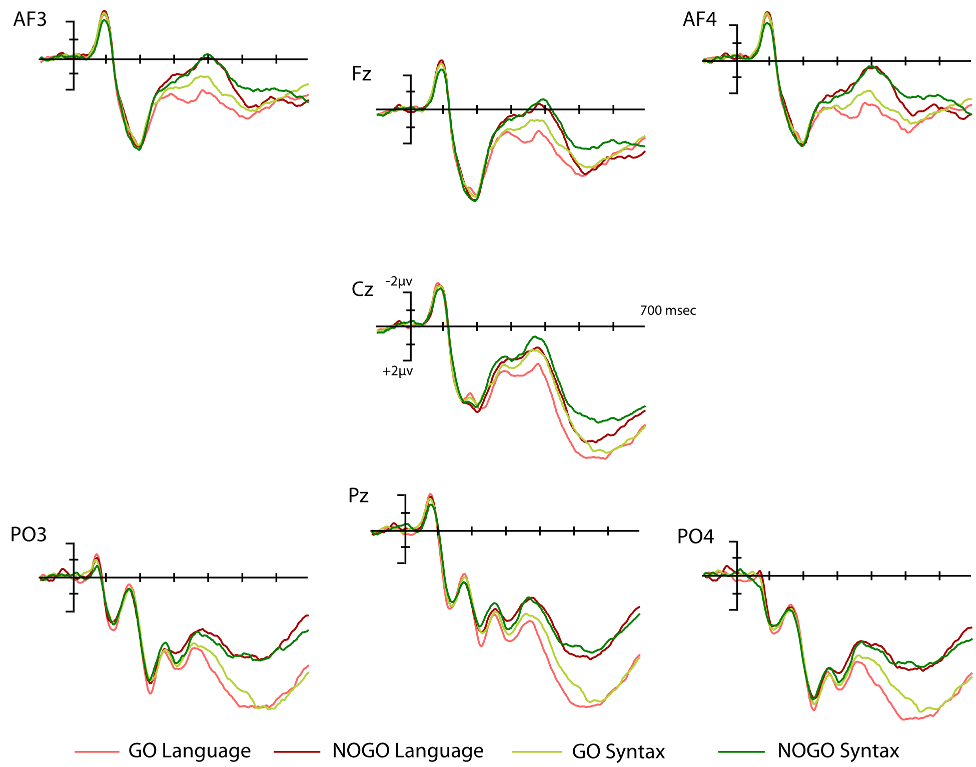

Fig. 5. Superimposed grand average ERPs for all four conditions in 7 representative electrodes.

words. There was, however, a significant main effect of trial type on the d' scores, $F(1,24)=4.29$, $p=0.05$, indicating that participants were less susceptible to false alarms and response errors when responding to words in Spanish in general.

3.2.2. N200 analysis

As in Experiment 1, we computed individual and grand average ERPs for the go and nogo trials for both the go/nogo=syntax and go/nogo=language conditions. On average, the percentage of

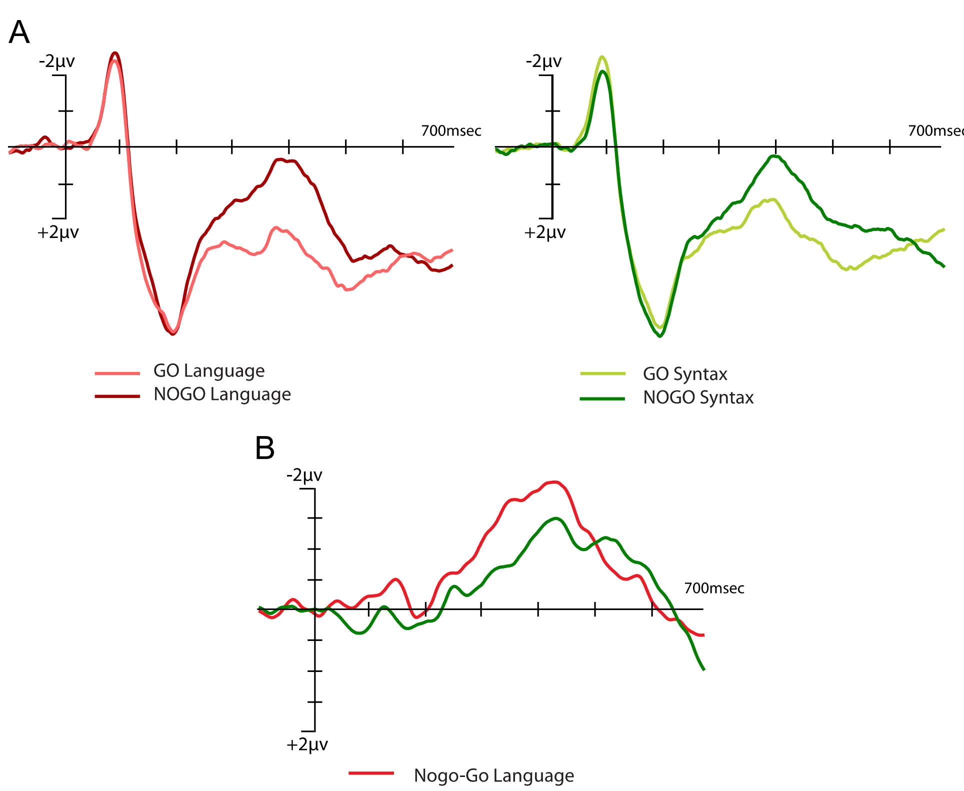

Fig. 6. (A) Grand average ERPs in the go/nogo=language condition (left) and the go/nogo=syntax condition (right) pooled across nine frontal electrodes. (B) Superimposed difference waves for the two conditions.

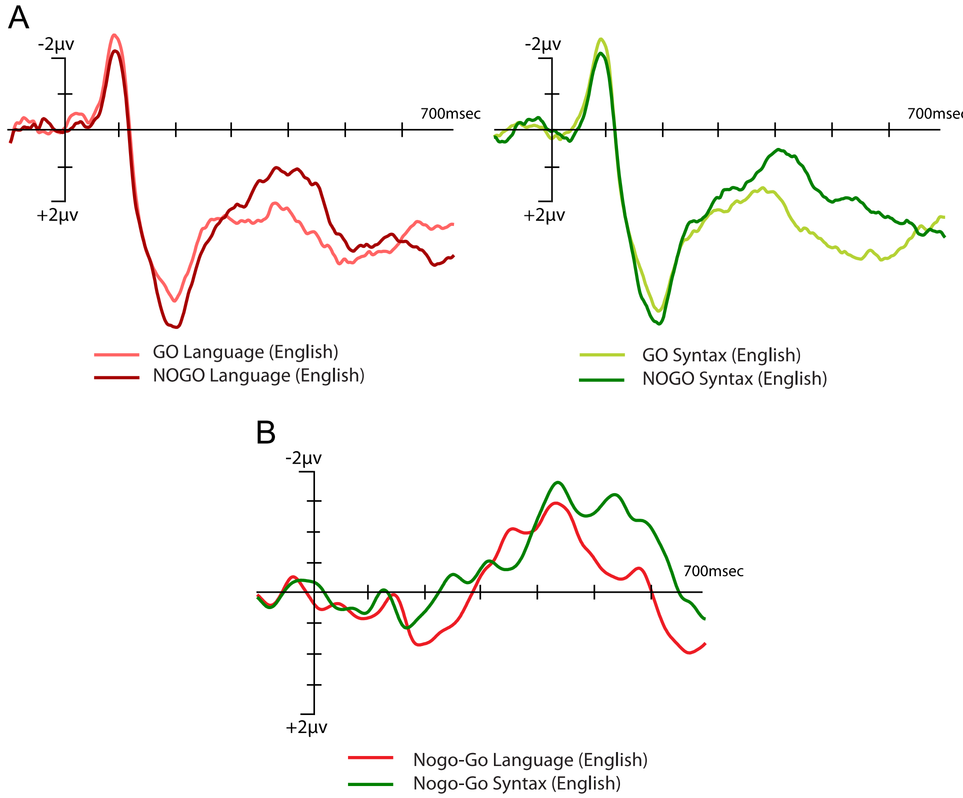

Fig. 7. (A) English trials. Grand average ERPs in the go/nogo=language condition (left) and the go/nogo=syntax condition (right) pooled across nine frontal electrodes. (B) Superimposed difference waves for the two conditions.

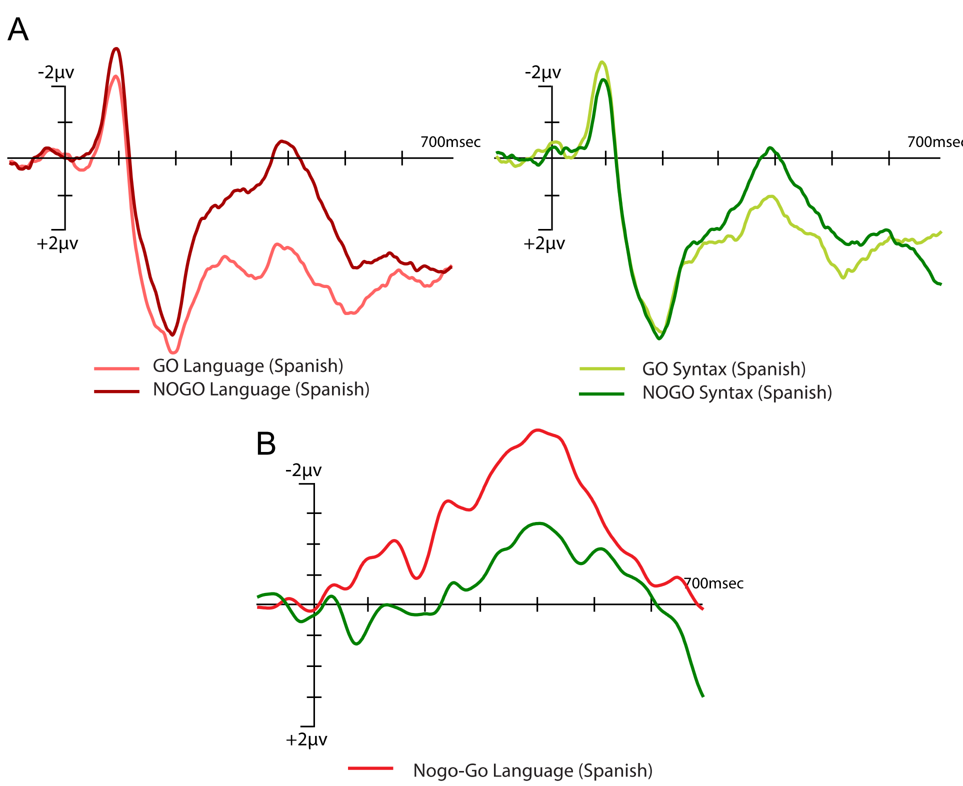

Fig. 8. Spanish trials. (A) Grand average ERPs in the go/nogo=language condition (left) and the go/nogo=syntax condition (right) pooled across nine frontal electrodes. (B) Superimposed difference waves for the two conditions.

artifact-free and correct response/nonresponse trials contributing to individual ERPs in each of the four conditions were: GO Language=82.5%, NOGO Language=81.8%, GO Syntax=83.4%, NOGO Syntax=82.9%.

Fig. 5 shows grand average ERPs to each of the four experimental conditions in seven representative electrodes. Again, we isolated the N200 effect for each condition by subtracting the waveforms for the go trials from the waveforms for the nogo trials. Both response contingency conditions showed a clear N200 effect, with nogo trials eliciting a larger negativity than go trials. Fig. 6 presents grand-average ERPs and corresponding difference waves for each condition collapsed across the nine frontal electrodes. Figs. 7 and 8 present the ERP data and difference waves split by trial type.

We focused our analyses on the same nine electrodes as in Experiment 1. Latencies and amplitudes were calculated in the same fashion as in Experiment 1. These values were analyzed in linear mixed effects models, with condition and trial type contrast-coded and included as fixed effects, and using the same random effects structure as in Experiment 1 (parameter estimates for all models are included in the Supplementary materials). Latency and amplitude values for each electrode site can be found in Appendix E. The same measures split by trial type can be found in Appendix F.

3.2.2.1. Onset latencies. The onset latencies for the two response contingencies were comparable, with the N200 for the go/nogo=language condition starting around 297 ms (SD=86.51) and the N200 for the go/nogo=syntax condition starting around 304 ms (SD=72.40; Estimate: 6.52 ms, Standard error: 21.62 ms, t=0.30, p=.76).

To test whether averaging across English and Spanish trials was obscuring latency differences within a particular language, we again broke our analyses down by trial type. Table 5 lists the average latency and amplitude values for each condition split by trial type. Although doing so reduced the number of trials that went into each individual and grand-average waveform in half (max=80), grand-average N200 effects appeared for both conditions in both trial types. However, three participants failed to show an N200 in at least one of the condition by trial type combinations after splitting the waveforms. These three participants were therefore excluded from the by trial type analyses, leaving 22 participants. On average, the percentage of artifact-free and correct response/nonresponse trials contributing to individual ERPs in each of the eight conditions were as follows: English: GO Language=81.1%, NOGO Language=82.6%, GO Syntax=83.5%, NOGO Syntax=83.6%. Spanish: GO Language=82.4%, NOGO Language=85.1%, GO Syntax=84.5%, NOGO Syntax=84.1%.

There was a marginally significant effect of trial type (Estimate: −20.62 ms, Standard error: 11.31 ms, t=−1.82, p=.07), with the N200 effects elicited by Spanish words starting earlier than those elicited by English words. However, this trial type effect did not interact with condition (Estimate: 18.42 ms, Standard error: 24.21 ms, t=0.76, p=.45), suggesting that the absence of an onset difference between the two response contingencies is independent of the language of the words participants had to respond to.

3.2.2.2. Peak latencies. The N200 effect for the go/nogo=language condition peaked around 434 ms (SD=92.09) while the N200 effect for the go/nogo=syntax condition peaked around 470 ms (SD=89.24). This 36-ms difference was significant when the trials were averaged across the two languages (Estimate: 33.74 ms, Standard error: 17.24, t=1.96, p=.05). Breaking the analysis down by trial type did not reveal any language differences (Estimate: −23.22, Standard error: 15.49, t=−1.50, p=.14) nor trial type by condition interaction (Estimate: −20.00, Standard error: 24.14, t=−0.83, p=.41), suggesting that the N200 peaked for the go/nogo=language condition earlier than the go/nogo=syntax condition irrespective of the language the task was performed in.

3.2.2.3. Peak amplitudes. The go/nogo=language condition elicited significantly larger N200 amplitudes (M=−3.99 μV, SD=2.07 μV) than the go/nogo=syntax condition (M=−3.34 μV, SD=1.66 μV; Estimate: 0.66 μV, Standard error: 0.31, t=2.13, p=.03) when averaged across English and Spanish trials. After breaking the analyses down by trial type, we see that this peak amplitude difference between conditions was driven largely by the N200 waveform elicited by the go/nogo=language condition in Spanish, which had a mean peak amplitude of −5.86 μV (SD=2.41). The peak amplitudes for the other condition by trial type combinations was around −4.20 to −4.40 μV (SD=1.99 to 2.54), leading to a significant condition by trial type interaction (Estimate: 1.83, Standard error: 0.79, t=2.30, p=.03).

3.2.2.4. Mean amplitudes. There was no mean amplitude difference between the go/nogo=language condition (M:−1.21 μV, SD=1.46) and the go/nogo=syntax condition (M:−0.83 μV, SD=1.44), (Estimate: 0.38, Standard error: 0.31, t=1.25, p=.21). Splitting by trial type, however, revealed a significant condition by trial type condition (Estimate: 1.75, Standard error: 0.73, t=2.39, p=.02) where the mean amplitude difference across languages was much greater in the go/nogo=language condition, likely due to the larger difference wave elicited by Spanish words.

3.3. Discussion

Experiment 2 examined the time course of access to language and syntactic information during visual word recognition. In contrast with Experiment 1, there were no differences in N200 onset latency between conditions, although the N200 peaked about 36 ms earlier in the go/nogo=language condition than in the go/nogo=syntax condition. This temporal pattern held for both English and Spanish words. Behaviorally, participants responded faster in the syntax than in the language condition but were more accurate in the language than in the syntax condition, possibly reflecting a speed-accuracy tradeoff. We think that the higher proportion of false alarms in the syntax condition may be due to the fact that many of the nouns could easily be turned into verbs or vice versa. In other words, the noun and verb forms of some of our lexical items share more similar orthography in English (e.g., *response* vs. *respond*, compared to the Spanish pair

Table 5
Mean latencies and amplitudes for the N200 waveforms split by trial type averaged across the nine frontal electrode sites. Standard deviations are in parentheses.

English words					Spanish words			
Condition	Onset latency (ms)	Peak latency (ms)	Peak amplitude (μV)	Mean amplitude (μV)	Onset latency (ms)	Peak latency (ms)	Peak amplitude (μV)	Mean amplitude (μV)
Go/nogo=language	314.94 (84.72)	446.39 (95.40)	−4.28 (2.54)	−0.46 (2.00)	287.92 (77.39)	433.72 (92.69)	−5.86 (2.79)	−1.84 (2.31)
Go/nogo=syntax	320.69 (69.52)	492.32 (85.79)	−4.39 (2.13)	−0.88 (1.61)	309.78 (61.21)	458.83 (92.20)	−4.22 (1.99)	−0.69 (2.13)

respuesta vs. *responder*). As a result, it may have been difficult to disambiguate whether the stimulus was a noun or a verb until the end of the word, which may have been later than disambiguating whether it was an English or a Spanish word. That is, participants may have sacrificed accuracy for a faster reaction time by making their syntactic decision prior to being completely sure. This difference may have been reflected in the delay in responding positively to English words behaviorally, particularly to English verbs, as well as in the smaller N200 amplitude observed in the syntax condition. Falkenstein et al. (1999) found that subjects with high false alarm rates tended to elicit a smaller N200 effect than subjects with a low false alarm rate, likely because the inhibition process is weakened in these particular subjects.[3] Alternatively, it could be that the latency of the N200 was more variable depending on individual differences on the speed-accuracy trade off, thus flattening the curve. However, when we break our analyses by trial type, we see that the particular language in which the words appeared had an effect only on behavioral differences, and not on the peak latency difference between conditions. That is, although less conclusive than in Experiment 1, language information was also accessed prior to syntactic information, independently of which language the word was presented in. It is important to point out that, in contrast with studies on language production, electrophysiological studies of auditory word processing (Holcomb and Neville, 1991; Rodriguez-Fornells et. al, 2002b) in monolinguals have found a less strictly serial process in favor of some temporal overlap between phonological and semantic analysis of a word, supporting a more parallel processing of information during comprehension (but see Müller and Hagoort, 2006 for evidence for earlier access to semantics than syntax during the reading of single words). Turning to bilinguals, it could be that syntactic information is also accessed more in parallel with language membership information. Currently there are no lemma representations in the BIA+ word identification system, so the model is underspecified regarding how syntactic information should be incorporated into the system. In addition, future studies could use a larger number of recording sites to carry out topographic analyses to explore the neural basis of the clearer earlier access to language membership when pitted against semantic information, as compared to syntactic information.

4. General discussion

In combination, the two experiments reported here suggest that when reading visually presented words, bilinguals access language membership earlier than semantic and syntactic information. The timing of access to each type of information was assessed via onset and peak latencies of the N200 ERP component. It has been suggested that the N200 reflects either response inhibition (Jodo and Kayama, 1992; Lavric et al., 2004) or general conflict monitoring (Enriquez-Geppert et al., 2010; Nieuwenhuis et al., 2003). In either case, task-relevant information is assumed to have been accessed before it can be used to either inhibit a response or to calibrate conflict, and thus the N200 can be used as a tool to estimate an upper bound on the timing of information access (in this case, access to different types of linguistic information). These results build on previous studies in monolinguals that used the N200 to estimate relative timing differences for phonological, semantic, and syntactic access (Müller and Hagoort, 2006; Rodriguez-Fornells et al., 2002b; Schmitt et al., 2000, 2001b). Here, we extended this work into the bilingual domain to study when access to language membership information occurs. Our results suggest that, at least for visual word recognition, language membership information was accessed prior to semantic and syntactic information.

Before discussing these results in a broader context, two specific points regarding the N200 should be noted. First, although the N200 effect on a simple go/nogo task can peak as early as 190 ms (Thorpe et al., 1996), our effects did not peak until after 400 ms. The N200 effect has been observed to be delayed with increased task difficulty (Gajewski and Falkenstein, 2013), and it is possible that our relatively complex dual-choice task placed an additional cognitive load on the participants. Our paradigm required participants to keep track of two types of information simultaneously. Not only did they have to decide whether or not to respond (based on one type of information), but they also had to decide which hand to use to respond (based on a different type of information). Furthermore, this later peak latency is not particular to our study. The absolute peak latency values for the N200 effects we obtained are within the 400–500 ms range observed by other researchers using a similar dual-choice paradigm (e.g., Rodriguez-Fornells et al., 2002b; Müller and Hagoort, 2006). In particular, when Müller and Hagoort looked at the timing of access to semantic and syntactic information in a group of monolinguals, they observed peak latencies of 454 ms when semantics was determining the go/nogo response and 554 ms when syntax served as the response contingency. We obtained peak latencies of 475 ms to semantics and 470 ms to syntax (obtained from two different groups of participants). Furthermore, the specific millisecond differentials between the times when various types of linguistic information are accessed with respect to each other seem to depend on many factors, such as the particular task chosen to reflect access to each type of information or the combined difficulty of the dual task. For example, in general we found shorter N200 latencies in the second experiment, even when comparing a similar task used in both studies (i.e., the language membership decision). Thus, what may be most important when using the N200 to estimate the timeline of access to various types of linguistic information in both the current and previous studies is *not* the precise timing of access to each linguistic representation, but rather the relative temporal ordering between them and whether this ordering follows a consistent pattern.

The second point worth noting about the N200 as measured here is our decision to report both the onset and the peak latency of the N200 component. We did this because although we reached similar conclusions with both measures, they were not identical. As Luck (2014) points out, measuring latency differences of any type is particularly difficult and no method is free from potential problems. Therefore, we followed Luck's advice in measuring onset latencies in the difference waves, rather than on the ERPs per se, and we used a fractional peak latency to determine onset. The cases where we found some discrepancy between onset and peak latency could be due to differences in the slope of the waveforms. It is ostensible that while the N200 component of two conditions can onset at the same time, a steeper slope could lead one waveform to reach its peak earlier than a waveform with a flatter slope (whatever the cause of a flatter slope is, task difficulty, higher inter-subject or inter-trial variability, or some other factor). Thus, it is possible that our analyses underestimated the relative difference between conditions. However, it is important to point out that various N200 studies have also used the onset, the peak latency, or both to infer the temporal order of the two processes under study (Müller and Hagoort, 2006; Schmitt et al., 2000).

Importantly, our current findings raise an apparent paradox when considered along prior findings from our own lab and from other labs. If language membership is accessed earlier than semantic and

[3] This finding is also compatible with our observation that the condition with the largest amplitude (go/nogo=language with Spanish words) also had the highest d' score numerically.

syntactic information, it is curious why during word recognition, bilinguals access words compatible with the initial sound in a language-independent manner (Canseco-Gonzalez et al., 2010) or why cross-lingual priming still occurs at the semantic (e.g., Martin et al., 2009) and syntactic levels (Kantola and van Gompel, 2011). In other words, why do bilinguals fail to use this information to constrain access to only the task-relevant language? Some models of bilingual word recognition have suggested that language membership information does not serve a functional role in the word identification system, and that language control is instead carried out by a system external to word recognition (Dijkstra and van Heuven, 2002). The BIA+ model, for example, proposes that language nodes have no top-down connections to the orthographic and phonological level representations, suggesting that they do not provide strong selection constraints on the initial set of lexical candidates that are activated upon the presentation of the visual input. In particular, they propose that language information becomes available too late to restrict the word activation process. However, the earlier access to language membership information observed here would suggest that, whether the word recognition system uses language membership information or not, this is not determined by timing limitations. It could be that, as suggested by Dijkstra and van Heuven (2002), the word recognition system is not optimized in bilingualism, perhaps because language nodes are tagging millions of words, but each word is only linked to one language node. Therefore, potential feedback from language nodes may be a lot less efficient than any activation going from word to language node.

It is also important to note that our paradigm (namely, recognition of isolated written words) 'forced' participants to access two types of information, pitting one against the other. In everyday language processing, however, it is rare that we need to make decisions about a single word. That is, although information about language membership provided by an individual item or a list of words may not be used to any great extent to facilitate processing of the target word (de Bruijn et al., 2001; Dijkstra et al., 2000), it is possible that cues from a sentential context may modulate bilingual word recognition. While prior studies have shown that the mere presence of a sentence context, along with the language cues it could provide, are not sufficient to constrain processing to the target language alone, bilinguals are able to exploit the rich semantic information provided by highly constrained sentences to restrict or decrease cross-language lexical competition (Schwartz and Kroll, 2006; but see van Assche et al., 2011). Context may be especially important for syntactic access. Wong and Chen (2012) have argued that the syntactic properties of a word are processed by a system which is different from the one used for lexical access, suggesting that much of the syntactic information is made available only after an integration process related to sentence or phrase processing occurs. Under this account, the role of a word's syntactic category may be minimal when the word is presented in isolation for recognition, which could explain why language membership information becomes available sooner in the current experiment. However, Sunderman and Kroll (2006) have shown that even relatively novice L2 learners can use the grammatical class of a word as a cue to avoid interference from form-related neighbors, suggesting that syntactic category information is engaged at some level, even in the absence of a rich surrounding context. The BIA+ model is currently underspecified regarding top-down influences on word recognition from the task schema system. Future work exploring how semantic, syntactic, and language cues interact in a connected discourse may help shed light on the mechanisms underlying bilingual lexical access during comprehension in more natural circumstances.

Although in both of our studies language membership was accessed early, studies in monolinguals have found that the processing of different types of information may not be completely independent. For example, Schiller et al. (2003) found that during visual word recognition, semantic and phonological information can exert an influence on syntactic processing. It could be that the situation is even more complex in bilinguals where, in addition to the factors typically involved in monolingual processing (semantic, syntactic, phonological, and contextual), information linked to the bilingual experience (such as frequency, fluency, similarity between languages, etc.) interact in complex ways to determine the time course observed in a particular situation.[4] This potential interaction may help explain why our results were independent of the particular language in which the words were presented, whereas Ng and Wicha (2013) observed a temporal re-ordering depending on the language serving as the target.[5] Ng and Wicha (2013) suggest that the more frequently a language is used, the faster the words are identified as members of that particular language. Indeed, factors such as frequency or recency of use have been proposed to modulate activation levels across languages, with lower activation levels associated with slower recognition (Dijkstra and van Heuven, 2002). While the experimental blocks in Ng and Wicha's study required participants to respond to a particular semantic category in one language (e.g., English 'people' words) while ignoring words from the other language and from the other semantic category, our participants were required to keep track of both languages and semantic categories continuously, either to choose which hand to use when responding, or to choose whether to respond or not. Notice that our waveforms are in general quite similar to Ng & Wicha's (compare their Fig. 6 and our Fig. 1) but notably, they had three conditions comparable to our two NOGO conditions and only one GO waveform (depending on which language was the target). This task difference may have led to higher and similar activation levels of both languages in our subjects, instead of the differential activation found by Ng and Wicha. However, as Ng & Wicha point out, when their participants had Spanish as the target language, they still saw temporary evidence of activation of 'English people' words. In contrast, and contrary to the proposal of similar activation of both languages in our subjects, we see no evidence of irrelevant language activation in our waveforms. Taken together, this may suggest that bilinguals are sensitive to factors that affect both local and global activation levels of their two languages. Therefore, the timeline of lexical access in bilinguals may not be independent of their bilingual experience.

Finally, we must consider the difference between these two languages' orthography-to-phonology mappings, with English being opaque while Spanish is a transparent language. For example, the BIA+ model of bilingual word recognition proposes direct links between lexical and sublexical orthography and phonology representational pools. Although we attempted to decrease early orthographic cues to language membership in our stimuli, this may have played an undetected role that could only be addressed in future studies with different pairs of languages varying in this dimension.

In sum, our results extend the time course of lexical access in comprehension to the bilingual domain by examining when language membership information is accessed relative to other lexical representations. In bilingual visual word recognition, language membership can be accessed before semantic and syntactic information, and this temporal ordering can hold regardless of which language is being used.

[4] We tried to examine this role of bilingual experience in our own data by adding age of acquisition, frequency of use, and self-reported proficiency levels for both English and Spanish as regression factors to our onset and peak latency models, but these factors did not reliably predict the observed timing difference between conditions ($ts < 1.50$).

[5] We compare their study with our Experiment 1 in particular, given that these two studies investigated access to semantic versus access to language membership information.

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Appendix A. List of stimuli in Experiment 1

	English animals	English objects	Spanish animals	Spanish objects
	ALLIGATOR	ALARM	ALONDRA	BASURA
	ANTEATER	ARMOR	ARDILLA	BOTELLA
	ANTELOPE	ARROW	BALLENA	CALCETA
	BISON	BANDAGE	BORREGO	CALCULADORA
	BULL	BRACELET	BURRO	CAMION
	CAMEL	BRANCH	CABALLO	CAMPANA
	CARP	BRICK	CABRA	CARPETA
	CATERPILLAR	CABINET	CALAMAR	CENICERO
	CENTIPEDE	CALENDAR	CAMARON	CINTA
	CHAMELEON	CARAVAN	CAMELLO	COCHE
	CRAB	CARPET	CANARIO	CUCHILLO
	CROCODILE	CARROT	CANGREJO	DIENTE
	CROW	CAULIFLOWER	CANGURO	ESCOBA
	DRAGONFLY	CHECK	CARACOL	FALDA
	DUCK	CLARINET	CASTOR	GALLETA
	FERRET	COMPUTER	COLIBRI	HAMACA
	FIREFLY	CONTAINER	COMEDREJA	HARINA
	GAZELLE	CURTAIN	CONEJO	HELADO
	GOLDFISH	DIAMOND	CORDERO	HORNO
	GORILLA	DIARY	DELFIN	IMPRESORA
	HORNET	GATE	ELEFANTE	LENTES
	HORSE	GLOVE	ESCARABAJO	LEVADURA
	LEOPARD	HELICOPTER	GALLINA	LIBRO
	LION	HELMET	GATO	MARCADOR
	LOBSTER	MARBLE	GOLONDRINA	MERCADO
	MARE	MOTORCYCLE	GRILLO	MESA
	MARMOSET	ORANGE	HORMIGA	MONEDA
	MILLIPEDE	PAIL	LAGARTO	PALA
	MONKEY	PAPER	MARIPOSA	PANECILLO
	MULE	PENCIL	MORSA	PANTALLA
	OSTRICH	PINEAPPLE	MOSCA	PANTALONES
	PANTHER	PRESENT	PALOMA	PIEDRA
	PARKEET	PROPELLER	PATO	REGALO
	PARROT	RADISH	PERRO	REGLA
	PENGUIN	REFRIGERATOR	PULPO	SANGRE
	PORCUPINE	TANK	RINOCERONTE	SELLO
	ROBIN	TENT	SAPO	SILLA
	SALAMANDER	TRUCK	SERPIENTE	SINTETIZADOR
	TURKEY	TURNIP	TOPO	TECLADO
	TURTLE	UMBRELLA	TRUCHA	VENTANA
Log word frequency	2.15 (SD=0.69)	2.65 (SD=0.60)	2.27 (SD=0.59)	2.76 (SD=0.75)
Log initial bigram frequency	8.43 (SD=1.06)	8.57 (SD=1.28)	8.19 (SD=1.13)	8.98 (SD=0.85)
Number of letters	6.69 (SD=1.95)	6.69 (SD=1.96)	6.69 (SD=1.65)	6.69 (SD=1.76)

Appendix B. List of stimuli in Experiment 2

	English nouns	English verbs	Spanish nouns	Spanish verbs
	ALLIGATOR	ARRANGE	ARBOL	ACEPTAR
	ARRIVAL	BOUGHT	BAILARIN	APRENDEN
	ARROW	CAUGHT	BASURA	CAMBIAR

	BRACELET	COMPLAIN	CABALLO	CANCELAR
	CABINET	COMPOSE	CAMION	CANTARE
	CALCULATOR	CONTINUE	CANCION	CERRAR
	CAMEL	CONTRIBUTE	CARACOL	COMPRAR
	CAMERA	CREATE	CAUTELA	CONDUCIR
	CHILD	DEFENDED	COCHE	CONTAR
	COMPUTER	DELIVER	COLCHON	CORRERAS
	DEPARTURE	DEMONSTRATE	CORAZON	CORTAR
	DIAMOND	DESCRIBED	DIENTE	CREER
	DIARY	DISTURB	ELECTRICIDAD	DESPERTE
	FAUCET	ENCOURAGE	ESCOBA	DORMISTE
	GARBAGE	ENTERED	ESCUELA	ENCENDER
	HAIR	FULFILL	FALDA	ENCONTRAR
	HELMET	GAVE	FAMILIA	ENTENDI
	HISTORY	GENERATE	GALLETA	ENVIAR
	INSIGHT	IMAGINE	HELADO	ESCOGI
	LANGUAGE	INFORM	IMPRESORA	ESCRIBEN
	LEADER	INTRODUCED	LENTES	ESPERO
	LOCKER	JUSTIFY	MARCADOR	ESTUDIE
	MARKER	LEARN	MARIPOSA	EXPLIQUE
	MELODY	MIGRATE	MARMOL	FIRMAR
	MICROPHONE	NOMINATE	MARTES	FUMASTE
	MIRACLE	ORGANIZE	MERCADO	GASTAS
	MONTH	PERFORM	MONEDA	HABLAS
	MUSIC	PREDICT	MONTON	LIMPIAR
	OPERATION	PROPOSE	MOSCA	MIRAR
	PARADISE	PROTECT	PANTALONES	NADARE
	PAYMENT	READ	PELIGRO	NECESITO
	PENGUIN	REPLACE	PERCHA	PAGAR
	PERFORM	REPRESENT	PERRO	PERDER
	PERSON	SAID	PROVECHO	PERMITIR
	PORCUPINE	SANG	RESPUESTA	PONER
	PRODUCT	SEND	SANGRE	PRESTARON
	RENEWAL	SOLVE	SERPIENTE	REPARAR
	RESPONSE	STRENGTHEN	SILLA	SENTARSE
	SAFETY	TOLD	TORTUGA	TERMINAR
	SOLUTION	UNCOVER	VENTANA	TOSER
Log word frequency	2.85 (SD=0.62)	2.89 (SD=0.78)	3.00 (SD=0.68)	2.94 (SD=0.81)
Log initial bigram frequency	9.01 (SD=0.62)	9.14 (SD=0.85)	9.16 (SD=0.86)	9.47 (SD=1.06)
Number of letters	6.90 (SD=1.45)	6.95 (SD=1.80)	6.85 (SD=1.48)	6.90 (SD=1.15)

Appendix C. Exp.1. Mean N200 latency and amplitude values for the nine frontal electrodes by condition. Standard deviations are in parentheses

	Go/Nogo=Language				Go/Nogo=Semantics			
Electrode site	Onset latency (ms)	Peak latency (ms)	Peak amplitude (μV)	Mean amplitude (μV)	Onset latency (ms)	Peak latency (ms)	Peak amplitude (μV)	Mean amplitude (μV)
Fp1	311.50 (65.12)	430.30 (45.66)	−3.76 (2.51)	−0.87 (1.32)	317.05 (59.87)	468.11 (66.55)	−3.89 (1.41)	−1.11 (1.24)
Fp2	306.68 (70.17)	461.16 (60.73)	−4.37 (2.13)	−1.24 (1.42)	333.70 (59.87)	466.40 (71.17)	−3.81 (1.61)	−1.00 (0.96)
AF3	298.10 (56.82)	430.40 (59.42)	−3.79 (1.83)	−1.17 (0.99)	337.00 (66.13)	471.50 (68.20)	−3.10 (1.23)	−0.81 (0.99)
AF4	307.40 (64.47)	442.50 (69.48)	−4.31 (2.03)	−1.49 (1.16)	324.20 (58.19)	475.00 (71.86)	−3.52 (0.95)	−1.01 (0.75)
F7	308.53 (55.05)	435.16 (43.13)	−2.47 (1.20)	−0.45 (0.93)	326.71 (71.58)	467.06 (68.94)	−2.45 (1.22)	−0.47 (1.08)
F3	309.20 (45.83)	440.20 (61.26)	−3.18 (1.41)	−0.92 (0.85)	345.20 (72.25)	477.10 (79.86)	−3.10 (1.41)	−0.76 (1.14)
Fz	318.50 (51.45)	443.00 (81.23)	−4.03 (1.67)	−1.24 (1.02)	335.89 (63.34)	472.53 (74.70)	−3.56 (1.67)	−0.91 (1.04)
F4	319.40 (47.62)	458.80 (79.19)	−4.10 (1.80)	−1.39 (0.96)	341.30 (51.48)	508.30 (66.79)	−3.66 (1.17)	−1.04 (0.79)
F8	296.30 (72.00)	438.90 (90.79)	−2.79 (0.96)	−0.79 (0.99)	335.80 (75.50)	466.10 (85.57)	−2.58 (1.02)	−0.58 (0.96)

Appendix D. Exp.1. Mean N200 latency and amplitude values for both response contingencies split by trial type. Standard deviations are in parentheses

		Go/Nogo = Language				Go/Nogo = Semantics			
Trial type	Electrode site	Onset latency (ms)	Peak latency (ms)	Peak amplitude (μV)	Mean amplitude (μV)	Onset latency (ms)	Peak latency (ms)	Peak amplitude (μV)	Mean amplitude (μV)
English words	Fp1	310.84 (81.99)	457.05 (72.05)	−3.76 (2.51)	−0.59 (2.25)	307.65 (59.33)	475.18 (73.99)	−4.94 (1.99)	−0.81 (2.18)
	Fp2	309.37 (98.65)	425.68 (83.24)	−4.37 (2.13)	−0.85 (1.89)	322.56 (56.26)	486.56 (82.10)	−4.94 (2.27)	−0.91 (1.63)
	AF3	303.79 (94.87)	449.68 (77.97)	−3.79 (1.83)	−1.02 (1.93)	347.58 (80.01)	473.26 (81.40)	−4.29 (1.57)	−0.99 (1.41)
	AF4	315.40 (81.39)	458.20 (75.54)	−4.31 (2.03)	−1.19 (2.21)	332.90 (56.41)	495.60 (78.26)	−4.85 (1.62)	−1.28 (1.16)
	F7	300.56 (70.89)	450.89 (73.22)	−2.47 (1.20)	−0.19 (1.41)	310.94 (94.14)	497.24 (86.75)	−3.60 (1.53)	−0.54 (1.58)
	F3	305.22 (69.84)	421.56 (80.09)	−3.18 (1.41)	−0.71 (1.64)	320.00 (87.97)	490.11 (75.27)	−4.28 (1.78)	−0.96 (1.52)
	Fz	325.26 (87.90)	445.26 (84.19)	−4.03 (1.67)	−0.79 (1.66)	314.00 (64.09)	452.70 (106.75)	−4.55 (2.13)	−1.24 (1.51)
	F4	340.10 (74.91)	467.70 (90.79)	−4.10 (1.80)	−1.05 (1.47)	323.50 (55.26)	486.80 (88.11)	−4.93 (1.70)	−1.49 (1.02)
	F8	301.90 (75.77)	441.10 (84.65)	−2.79 (0.96)	−0.47 (1.57)	312.30 (80.70)	469.50 (82.96)	−3.62 (1.31)	−0.83 (0.99)
Spanish words	Fp1	297.07 (63.99)	446.63 (79.87)	−5.78 (3.17)	−0.59 (3.04)	331.20 (60.92)	461.20 (64.71)	−5.26 (2.23)	−1.35 (2.67)
	Fp2	294.11 (71.83)	450.78 (63.32)	−5.66 (3.42)	−1.50 (1.64)	340.00 (59.65)	476.42 (72.45)	−5.19 (2.09)	−1.16 (1.71)
	AF3	297.33 (82.53)	444.22 (70.53)	−4.95 (2.69)	−1.00 (2.09)	352.90 (54.86)	448.40 (93.30)	−3.63 (1.21)	−0.63 (1.17)
	AF4	302.50 (61.73)	459.00 (91.76)	−5.31 (2.93)	−1.57 (1.99)	348.00 (62.07)	455.60 (91.56)	−3.79 (1.57)	−0.74 (1.45)
	F7	310.75 (74.47)	439.00 (49.49)	−4.28 (1.91)	−0.67 (1.83)	334.70 (59.54)	429.30 (91.86)	−2.90 (1.17)	−0.48 (0.86)
	F3	296.32 (71.34)	444.32 (78.64)	−4.83 (2.61)	−1.06 (1.99)	347.10 (59.48)	450.10 (102.98)	−3.64 (1.62)	−0.55 (1.27)
	Fz	315.60 (64.19)	420.20 (73.98)	−5.29 (3.03)	−1.24 (1.97)	344.00 (65.11)	457.20 (102.87)	−3.88 (2.02)	−0.55 (1.38)
	F4	314.30 (59.48)	453.10 (90.63)	−5.51 (2.75)	−1.61 (1.90)	334.30 (65.89)	479.20 (95.84)	−3.73 (1.71)	−0.61 (1.29)
	F8	287.60 (68.77)	444.60 (69.91)	−3.81 (1.63)	−1.19 (1.46)	329.78 (84.10)	489.44 (96.99)	−3.10 (1.34)	−0.36 (1.37)

Appendix E. Exp. 2. Mean N200 latency and amplitude values for the nine frontal electrodes by condition. Standard deviations are in parentheses

	Go/Nogo = Language				Go/Nogo = Syntax			
Electrode site	Onset latency (ms)	Peak latency (ms)	Peak amplitude (μV)	Mean amplitude (μV)	Onset latency (ms)	Peak latency (ms)	Peak amplitude (μV)	Mean amplitude (μV)
Fp1	290.48 (92.35)	429.12 (90.03)	−4.35 (2.30)	−1.39 (1.65)	290.56 (72.84)	471.76 (79.90)	−3.31 (1.71)	−0.88 (1.30)
Fp2	287.04 (92.72)	439.12 (78.60)	−4.51 (2.42)	−1.56 (1.78)	311.52 (70.38)	467.84 (91.48)	−3.74 (1.61)	−1.02 (1.21)
AF3	291.04 (92.29)	427.92 (97.57)	−4.13 (2.01)	−1.27 (1.45)	289.28 (72.84)	479.20 (93.51)	−3.26 (1.75)	−0.88 (1.60)
AF4	297.36 (93.44)	432.56 (91.94)	−4.13 (2.10)	−1.34 (1.50)	300.40 (72.84)	477.52 (91.02)	−3.76 (1.53)	−1.08 (1.47)
F7	278.75 (70.08)	429.83 (99.98)	−3.03 (1.14)	−0.73 (1.03)	324.17 (85.47)	450.26 (81.48)	−2.11 (1.00)	−0.26 (1.21)
F3	311.92 (86.69)	427.36 (98.10)	−3.88 (2.14)	−1.16 (1.44)	298.83 (57.56)	457.25 (92.58)	−3.26 (1.88)	−0.77 (1.64)
Fz	302.64 (97.65)	420.40 (103.28)	−3.93 (2.25)	−0.94 (1.54)	296.33 (81.13)	477.25 (91.80)	−3.81 (1.98)	−0.88 (1.80)
F4	312.08 (93.46)	446.80 (94.26)	−4.37 (2.17)	−1.44 (1.45)	312.42 (61.25)	481.00 (95.01)	−3.97 (1.58)	−1.06 (1.56)
F8	299.83 (58.96)	453.25 (82.60)	−3.52 (1.65)	−1.09 (1.23)	315.20 (67.84)	470.32 (94.89)	−2.83 (1.00)	−0.66 (1.09)

Appendix F. Exp. 2. Mean N200 latency and amplitude values for both response contingencies split by trial type. Standard deviations are in parentheses

		Go/Nogo = Language				Go/Nogo = Syntax			
Trial type	Electrode site	Onset latency (ms)	Peak latency (ms)	Peak amplitude (μV)	Mean amplitude (μV)	Onset latency (ms)	Peak latency (ms)	Peak amplitude (μV)	Mean amplitude (μV)
English words	Fp1	319.65 (79.99)	443.74 (84.13)	−4.95 (2.63)	−0.72 (2.15)	312.92 (70.86)	485.92 (78.31)	−4.12 (1.91)	−0.85 (1.52)
	Fp2	312.69 (85.90)	448.70 (92.24)	−5.17 (3.40)	−0.81 (2.68)	304.00 (73.20)	464.17 (96.95)	−4.44 (2.07)	−0.92 (1.68)
	AF3	323.17 (74.80)	430.42 (102.81)	−3.94 (2.29)	−0.41 (1.75)	312.25 (68.87)	487.92 (87.36)	−4.31 (2.39)	−0.90 (1.75)
	AF4	316.42 (76.19)	444.50 (95.04)	−4.24 (2.51)	−0.63 (2.10)	310.67 (63.07)	511.75 (86.32)	−4.71 (1.77)	−1.18 (1.51)
	F7	289.82 (89.46)	429.27 (102.68)	−3.53 (1.65)	−0.08 (1.57)	333.18 (77.96)	480.82 (87.37)	−2.95 (1.92)	−0.20 (1.52)

	F3	309.27 (85.11)	431.18 (90.52)	−4.09 (2.09)	−0.30 (1.71)	309.27 (74.33)	484.43 (83.55)	−4.33 (2.49)	−0.84 (1.79)
	Fz	306.29 (82.30)	430.00 (101.62)	−4.12 (2.24)	−0.10 (1.97)	304.50 (68.04)	481.75 (88.53)	−4.88 (2.65)	−1.09 (1.87)
	F4	310.00 (79.60)	467.75 (95.97)	−4.36 (2.56)	−0.59 (2.05)	325.92 (77.09)	513.75 (88.03)	−4.92 (2.56)	−1.22 (1.54)
	F8	328.25 (103.96)	438.52 (102.68)	−3.94 (2.28)	−0.48 (2.05)	316.48 (92.14)	468.16 (108.16)	−3.44 (1.03)	−0.74 (1.21)
Spanish words	Fp1	296.80 (83.18)	428.72 (98.02)	−5.78 (2.86)	−1.86 (2.68)	304.25 (83.18)	442.67 (80.79)	−4.60 (1.90)	−0.83 (2.05)
	Fp2	270.48 (74.27)	413.68 (93.39)	−5.97 (2.62)	−2.09 (2.70)	303.36 (63.69)	458.16 (98.51)	−4.56 (2.09)	−1.00 (1.86)
	AF3	282.08 (81.54)	433.44 (92.76)	−5.74 (3.01)	−2.02 (2.46)	297.08 (54.24)	454.17 (86.82)	−4.17 (1.68)	−0.77 (2.21)
	AF4	292.24 (78.41)	420.00 (95.38)	−5.65 (2.81)	−1.92 (2.31)	300.25 (69.67)	462.42 (96.75)	−3.36 (1.93)	−0.88 (2.13)
	F7	290.16 (79.34)	413.36 (101.74)	−4.29 (1.90)	−1.25 (1.83)	304.67 (81.22)	407.17 (88.66)	−2.88 (1.12)	−0.28 (1.84)
	F3	268.96 (78.07)	413.36 (95.14)	−5.78 (3.37)	−1.96 (2.52)	296.75 (49.54)	443.42 (92.53)	−4.15 (2.03)	−0.63 (2.53)
	Fz	289.76 (73.87)	430.08 (103.06)	−5.88 (3.33)	−1.73 (2.38)	299.92 (56.40)	444.42 (102.36)	−4.47 (2.15)	−0.57 (2.72)
	F4	278.08 (73.35)	435.42 (99.94)	−6.12 (2.85)	−2.20 (2.13)	314.92 (59.70)	458.83 (99.92)	−4.70 (2.02)	−0.80 (2.18)
	F8	281.92 (71.35)	437.36 (85.37)	−4.47 (1.99)	−1.55 (1.82)	316.00 (61.58)	471.52 (105.44)	−3.36 (1.84)	−0.45 (1.66)

Appendix G. Supplementary material

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.neuropsychologia.2015.06.018.

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