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

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ABSTRACT

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.