Neuropsychologia 103 (2017) 183–190

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

Early processing of orthographic language membership information in bilingual visual word recognition: Evidence from ERPs

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ARTICLE INFO

Keywords:
Bilingualism
Visual word recognition
Language membership
Orthography
Bigram frequency

ABSTRACT

For successful language comprehension, bilinguals often must exert top-down control to access and select lexical representations within a single language. These control processes may critically depend on identification of the language to which a word belongs, but it is currently unclear when different sources of such language membership information become available during word recognition. In the present study, we used event-related potentials to investigate the time course of influence of orthographic language membership cues. Using an oddball detection paradigm, we observed early neural effects of orthographic bias (Spanish vs. English orthography) that preceded effects of lexicality (word vs. pseudoword). This early orthographic pop-out effect was observed for both words and pseudowords, suggesting that this cue is available prior to full lexical access. We discuss the role of orthographic bias for models of bilingual word recognition and its potential role in the suppression of nontarget lexical information.

1. Introduction

For successful language production and processing, bilinguals need to determine which of their languages is relevant in a given context and select representations that belong to the appropriate language. During comprehension, this requires identification of the language to which the input belongs. Some evidence suggests that this language membership information may guide the word recognition process toward representations belonging to the target language to improve the efficiency of lexico-semantic processing (Casaponsa et al., 2014; Casaponsa and Duñabeitia, 2016; Hoversten et al., 2015). For this process to occur, language membership information must be available very early during lexical access. Therefore, it is critical to establish the precise timing of the availability of language membership information for a complete understanding of the bilingual word recognition system.

The Bilingual Interactive Activation Plus (BIA+) model of bilingual visual word recognition includes sublexical, lexical, and semantic units as well as language nodes that represent language membership information (Dijkstra and Van Heuven, 2002). These language nodes are activated via lexical representations. However, recent studies suggest that bilinguals are sensitive to language membership information from other sources as well. Several studies have proposed that phonological cues that differ across languages can help bilinguals identify the appropriate language during spoken language processing (e.g., Gonzales and Lotto, 2013). Prior experience with a particular speaker may provide cues to help identify the language membership of incoming input as well (e.g., Martin et al., 2016).

During reading, bilinguals have also shown sensitivity to *orthographic* regularities, which differ systematically across languages (Vaid and Frenck-Mestre, 2002). For language pairs such as Chinese and English, the languages can be distinguished based on low-level visual features (e.g., logographic vs. alphabetic script), but languages that share scripts can contain orthographic language membership information as well. Many languages that use the same basic script contain language-specific letters (e.g., æ, ø, and å in Norwegian) that can aid in language attribution. Even for overlapping orthographies, the frequency of different letter combinations (i.e., bigram frequency) differs across languages (Oganian et al., 2016).

1.1. Orthographic language membership information

Converging evidence has demonstrated that orthographic language membership cues are used in a variety of behavioral tasks including lexical and language decisions. Stimuli that contain language-specific letters or bigrams that are illegal or improbable in the other language (marked stimuli) reduce language decision response times compared to orthographically unmarked stimuli (Casaponsa et al., 2014; Oganian et al., 2016; Vaid and Frenck-Mestre, 2002; van Kesteren et al., 2012). For example, van Kesteren et al. (2012) tested the effects of orthographic markedness in language and lexical decision tasks in

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http://dx.doi.org/10.1016/j.neuropsychologia.2017.07.026
Received 14 February 2017; Received in revised form 29 June 2017; Accepted 21 July 2017
Available online 22 July 2017
0028-3932/ Published by Elsevier Ltd.

Norwegian-English bilinguals. While they found robust effects in the language decision task, these effects depended on stimulus list composition for their lexical decision tasks. When participants performed an English lexical decision on a list of English words and pseudowords that could be marked for either language, markedness effects were only found for Norwegian pseudowords. Similarly, when the task was a Norwegian lexical decision on a list of Norwegian words and pseudowords marked for either language, markedness effects were only found for English pseudowords. The authors argued that this pattern of results demonstrates that orthographic language membership cues are only used when they are a reliable indicator of the correct response and that the locus of these effects is in post-lexical task/decision processes.

Orthographic markedness has been found to predict language decision latency even when factors such as orthographic neighborhood density are controlled, suggesting that these effects do not depend on co-activation of near neighbors (Casaponsa et al., 2014; Oganian et al., 2016; van Kesteren et al., 2012). Moreover, unique effects of continuous sublexical (bigram frequency) and lexical (orthographic neighborhood) statistics have been found in language decision tasks using languages with overlapping orthographies (Oganian et al., 2016). Because these markedness effects have been observed for both words and pseudowords (Lemhöfer and Dijkstra, 2004; Lemhöfer and Radach, 2009; van Kesteren et al., 2012), it is possible that these effects operate at a pre-lexical processing stage. However, to our knowledge, the time course of access to orthographic language membership information has not yet been directly tested.

1.2. Architecture of the bilingual word recognition system

To accommodate their results, van Kesteren et al. (2012) proposed an extension to the BIA+ model of visual word recognition, which includes separate sets of lexical and sublexical language nodes that receive activation from lexical and sublexical units respectively. Both sets of nodes feed information on to the task decision system that controls responses for a particular task. According to the current BIA+ model, "language information becomes available rather late during bilingual visual word recognition, usually too late to affect the word selection process" (Dijkstra and van Heuven, 2002, p. 186). Therefore, the language nodes do not have interactive feedback connections to the word recognition stream and hence cannot affect word identification processes directly. In this way, bilingual word recognition proceeds without regard to the language membership of a word (i.e., access is non-selective).

The extended version of the model proposed by van Kesteren and colleagues successfully accounts for the evidence that bilinguals are sensitive to orthographic language membership cues. It is also consistent with the body of evidence that bilingual word recognition is fundamentally non-selective (Kroll et al., 2006). While this model is a promising step forward, it does not accommodate the growing body of evidence suggesting that the nontarget language may be less active than the target language (i.e., access is at least partially selective), at least under certain conditions (Elston-Güttler et al., 2005; Hoversten and Traxler, 2016; Titone et al., 2011). For example, using a dual categorization task, Hoversten et al. (2015) showed event-related potential (ERP) evidence that language membership information is available prior to semantic information. Additionally, the N400 frequency effect was reduced for the nontarget compared to the target language. These results support the hypothesis that, contrary to the BIA+, the relatively early availability of language membership information contributes to subsequent suppression of nontarget language representations.

Furthermore, a series of studies by Casaponsa and colleagues has indicated that orthographic language membership cues in particular may play a critical role in restricting cross-language activation. In one study, markedness of Basque words decreased reaction times for Spanish-Basque bilinguals in a progressive demasking task, even though markedness was not a reliable indicator of the correct response (Casaponsa et al., 2014). In another study, bilinguals showed evidence for reduced top-down feedback from lexical to sublexical levels of representation for marked compared to unmarked Basque stimuli in a forced choice letter detection task. In a second experiment, the same participants showed robust masked translation priming effects for unmarked Basque primes on lexical decision for Spanish target words, whereas no translation priming effect was found for marked Basque primes (Casaponsa and Duñabeitia, 2016). Finally, a third study compared the effects of Spanish and Basque masked primes on processing of subsequent Spanish targets during electroencephalogram (EEG) recording. Switch costs on the N250 and N400 ERP components were found for target Spanish words preceded by marked Basque primes, but no switch costs were found when targets were preceded by unmarked Basque primes (Casaponsa et al., 2015). Together, these studies suggest that orthographic language membership information may participate directly in word identification processes by narrowing the search space to a single language.

1.3. The current experiment

Although one of the key predictions of the BIA+ model is that language membership information arrives late and cannot directly affect the word recognition process, these recent studies show evidence to the contrary. We hypothesized that the time course of sublexical language membership information could explain how orthographic markedness constrains cross-language activation and how language membership information modulates the depth of processing of target and nontarget languages. If orthographic language membership information is available early enough, it could influence subsequent lexico-semantic processing. In other words, orthographic cues may uniquely permit these early effects of language membership specifically because they are used early during word recognition. If, on the other hand, orthographic language membership information is not available until later during word recognition- as proposed by the BIA+ model- it would not have time to influence ongoing lexico-semantic processing in real time and may instead operate on post-lexical task/decision processes (van Kesteren et al., 2012).

Therefore, this study was designed to test different hypotheses about the mechanisms of bilingual word recognition by establishing precisely *when* orthographic language membership information is first available. To do so, we recorded EEG in a group of Spanish-English bilinguals during an oddball task in which participants saw frequent nontarget words in one language and infrequent target words in the other language. Rare task-relevant oddball stimuli are known to elicit N2 and P3 effects, which index the amount of time required to perform the necessary categorization task (Luck, 2005). In order to elicit these pop-out effects, we chose words typical of the language to which they belonged according to their orthographic regularities. This orthographic typicality was captured in an *orthographic bias* measure of the ratio between Spanish and English mean bigram frequencies for a given stimulus. Using this measure, we chose a set of Spanish and English words across a broad range of orthographic bias values. While some stimuli contained bigrams that are illegal in the other language (e.g., "sk" in *skipper*), other stimuli contained bigrams that were moderately biased toward one language (e.g., "qu" in *queso* is much more common in Spanish than in English) or weakly biased (e.g., "in" in *inner* is slightly more common in English).

Critically, we also included pseudowords with orthography that resembled either the target or the nontarget language. Although these pseudowords did not require a response, we used ERPs to determine whether participants would initially categorize target-like pseudowords as task-relevant based on orthographic information (as indicated by oddball N2 and P3 effects). If bilinguals are indeed sensitive to orthographic bias information even in the absence of lexical information, target-like pseudowords should produce oddball ERP effects similar to those of the infrequently presented target words. Nontarget-like

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