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Effects of speed of word processing on semantic access: The case of bilingualism

Clara D. Martin [a,*], Albert Costa [a,b], Benjamin Dering [c], Noriko Hoshino [d], Yan Jing Wu [c], Guillaume Thierry [c,d]

[a] Departament de Tecnologies de la Informació i les Comunicacions, Universitat Pompeu Fabra, Barcelona, Spain
[b] Institució Catalana de Recerca i Estudis Avançats, Spain
[c] School of Psychology, Bangor University, Bangor, UK
[d] Economic and Social Research Council Centre for Research on Bilingualism in theory and Practice, Bangor University, Bangor, UK

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ABSTRACT

Bilingual speakers generally manifest slower word recognition than monolinguals. We investigated the consequences of the word processing speed on semantic access in bilinguals. The paradigm involved a stream of English words and pseudowords presented in succession at a constant rate. English–Welsh bilinguals and English monolinguals were asked to count the number of letters in pseudowords and actively disregard words. They were not explicitly told that pairs of words in immediate succession were embedded and could either be semantically related or not. We expected that slower word processing in bilinguals would result in semantic access indexed by semantic priming. As expected, bilinguals showed significant semantic priming, indexed by an N400 modulation, whilst monolinguals did not. Moreover, bilinguals were slower in performing the task. The results suggest that bilinguals cannot discriminate between pseudowords and words without accessing semantic information whereas monolinguals can dismiss English words on the basis of subsemantic information.

1. Introduction

One of the fundamental issues in bilingualism research is to understand in which way language processing is affected by having to handle two languages simultaneously. This issue has been studied from different angles. Probably the most pervasive phenomenon associated with bilingualism is that individuals handling two languages generally manifest slower language processing than their monolingual peers (see for instance De Groot et al., 2002; Gollan et al., 2011). This slowing effect is found not only when participants are tested in their second language (L2) but also their first and dominant language (L1). For example, bilinguals speaking in L2 tend to produce sentences (MacKay & Fledge, 2004) and name pictures slower than monolinguals (Gollan et al., 2005, 2011; Kohnert et al., 1998; Roberts et al., 2002). Remarkably, this disadvantage seems to be also present when bilinguals produce language in L1 (Ivanova & Costa, 2008).

Of crucial interest in the present study is the often observed slower word recognition in bilinguals as compared to monolinguals. Bilinguals are slower in a wide range of word recognition tasks such as word list recognition (Ransdell & Fischler, 1987), non-word detection (Soares & Grosjean, 1984) and lexical decision (i.e., in differentiating words and non-words; Duyck et al., 2008; Gollan et al., 2011; Lehtonen & Laine, 2003; Portin & Laine, 2001; Ransdell & Fischler, 1987; Van Heuven et al., 1998; but see Dijkstra et al., 1998 for different effects depending on the lexical status of words and task). Here, we set out to study one potential consequence of this difference in processing speed between monolinguals and bilinguals, namely whether it affects access to the semantic representation of words. In particular, we test the hypothesis that this slowing down may lead to the activation of semantic representations in bilinguals, even when a task does not require semantic access.

One tool frequently used to investigate spontaneous semantic activation in word processing is the semantic priming paradigm. Semantic priming refers to the facilitated processing of a target word when it is preceded by a semantically related prime word. Several behavioral and electrophysiological studies have shown that semantic priming occurs or not, depending on the amount of attention dedicated to the prime word. For instance, semantic facilitation of target word processing can be attenuated or suppressed when participants process the prime in a relatively shallow fashion (e.g., letter searching task; Friedrich et al., 1991; Henik et al., 1983; Hoffman & MacMillan, 1985). These results suggest that semantic priming is not fully automatic and depends on the processing of the prime word. Based on this observation, we hypothesized that semantic priming relates to word processing speed: Fast

* Corresponding author. Address: Departament de Tecnologies de la Informació i les Comunicacions, Universitat Pompeu Fabra, C. Roc Boronat, 138, 08018 Barcelona, Spain. Fax: +34 93 542 25 17.
E-mail address: claramartin3@gmail.com (C.D. Martin).

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processing of the prime might suppress semantic facilitation of target processing, whereas a slow processing of the prime might induce semantic facilitation of target processing.

In the present study, we aimed at investigating the consequences, on semantic access, of slow word processing in bilinguals. Monolingual and bilingual participants were compared in a lexical decision/letter counting paradigm (differentiation of words and pseudowords/letter counting in pseudowords), in which semantic processing of unattended words could be assessed through semantic priming. Based on previous research on semantic priming, our hypothesis was that word processing would be fast in monolinguals and that, consequently, there would be no semantic facilitation of target word processing. On the other hand, we hypothesized that slower word processing in bilinguals would lead to word meaning access and, consequently, semantic priming.

To test this hypothesis, we will take advantage of a paradigm developed by Martin et al. (2009) testing spontaneous semantic priming in participants engaged in a language decision/letter counting task. Highly proficient early Welsh-English bilinguals were presented with a pseudo-randomised stream of Welsh and English words shown one at a time. They indicated whether words in one of their languages (the 'active' language; e.g., Welsh) were more or less than five letters in length and disregarded words in the other language ('unattended' language; e.g., English). Critically, the word stream was structured such that two words in a row could be semantically related or unrelated. Event-related brain potentials (ERPs) time-locked to the presentation of the words were analyzed in four conditions: Words 'active' or 'unattended' and semantically related or unrelated to the preceding word. Martin et al. (2009) evaluated semantic priming from the modulation of the N400 wave (Kutas and Hillyard, 1980) and found that word meaning was accessed in both the attended and the unattended languages, irrespective of the language under focus. In other words, bilinguals spontaneously access semantic representations when they are engaged in a language decision/letter counting task, and despite the fact that semantic information is irrelevant.

In this previous experiment, bilinguals processed irrelevant semantic relationships within a stimulus stream, as indexed by N400 modulations. In the present experiment, we tested the hypothesis that they do so because of the slowness of word processing. Accordingly, we expected monolingual participants not to display irrelevant semantic processing because of faster word processing under the same conditions. Whilst Martin et al. (2009) used words in two languages, here participants were presented with English words and pseudowords. The letter counting task was performed on pseudowords and the English words had to be disregarded. In sum, bilingual participants were expected to show significant semantic priming on English words whereas monolinguals were expected to show reduced or suppressed semantic priming.

2. Materials and methods

2.1. Participants

Fifteen native English speakers (13 females; mean age = 20.6 - years ± 5.2) and 15 native Welsh-English bilinguals (9 females; 22.9 years ± 4.6) took part in the experiment. Bilingual participants learned both languages at an early age (mean age of acquisition of English = 2.6 years ± 1.8/mean age of acquisition of Welsh = 2.7 - years ± 2.0) and did not speak any other language fluently. They used both languages on an everyday basis, at home and/or at University. None of the monolingual participants spoke any other language fluently. Monolingual participants rated their global proficiency in English at 9.4 ± 0.8 on a scale from 1 (very poor level) to 10 (perfectly fluent). The rating was based on reading, writing, listening, and speaking skills. They rated their proficiency in their second language (all participants at least learned a second language at school) at 2.9 ± 1.7. Bilingual participants rated their global proficiency in English at 9.4 ± 0.7 and their proficiency in Welsh at 9.3 ± 0.8. They rated their proficiency in their third language level at 3.0 ± 1.7. All participants gave written consent to take part in the study that was approved by the ethics committee of Bangor University, Wales, UK.

2.2. Stimuli and procedure

Stimuli were 156 familiar English nouns selected from the MRC psycholinguistic database (Coltheart, 1981) and 156 pseudowords (pronounceable letter strings without meaning in English or in Welsh). The 156 English words and 156 pseudowords were repeated 4 times across the experiment (never in the same block), twice as fillers and twice as critical stimuli. Thus, participants were presented with a one-by-one stream of 1248 pseudo-randomized words and pseudowords, in 8 blocks of 156 stimuli. Among the 1248 stimuli, 624 were fillers (156 words and 156 pseudowords repeated twice) and 624 were critical stimuli (156 words and 156 pseudowords repeated twice). Participants were not aware that the 624 critical stimuli were presented in succession as 312 pairs: 156 pairs of pseudowords, 78 pairs of semantically related words and 78 pairs of semantically unrelated words. Each of the 156 English words was used once in a semantically related pair and once in a semantically unrelated pair. Semantic relatedness was controlled based on a rating procedure conducted with 30 native English speakers using a Likert scale (1 = unrelated, 5 = strongly related; Table 1). Semantically related pairs were significantly more related than semantically unrelated pairs ($p < .0001$).

Participants were asked to count the number of letters in pseudowords and disregard English words. They had to press a designated button for pseudowords longer than five letters, another button for pseudowords with five letters or less, and withhold their response after English words. All items were presented one after the other at fixation for 200 ms, separated by an interval of 800 ms. Block order and response sides were counterbalanced to cancel out carry over effects.

Reaction times and accuracy were extracted from button press responses (correct detections for pseudowords and false alarms to English words). ERPs were analyzed for each target item of a pair in three conditions: semantically related English target word, semantically unrelated English target word, and target pseudoword (Table 1).

2.3. Electrophysiological recording and data analyses

Electrophysiological data were recorded in reference to electrode Cz at a rate of 1 kHz from 64 Ag/AgCl electrodes placed according to the 10–20 convention. Impedances were kept below 5 kΩ. EEG activity was filtered on-line band pass between 0.1 Hz and 200 Hz and re-filtered off-line with a 25 Hz low pass zero phase shift digital filter. Eye blink artifacts were mathematically corrected based on a model artifact computed from a minimum of 50 individual artifacts in each participant using the procedure implemented in Scan 4.3 (Neuroscan, Inc., El Paso, TX, USA) and remaining artifacts were manually dismissed. Epochs ranged from −100 to 1000 ms after the onset of target presentation. Baseline correction was performed in reference to pre-stimulus activity and individual averages were digitally re-referenced to a bi-mastoidic reference.

ERP components were defined based on the mean global field power measured across the scalp, which summarizes the contribution of all electrodes in the form of a single vector norm (Picton