Language Switching in a Picture Naming Task: An ERP Study

By Evan West

Abstract

Language switching was investigated in 13 unbalanced bilinguals (L1 English, L2 French, no L3) using the EEG recording technique. ERPs were recorded to images preceded by printed words. Subjects performed a semantic categorization task on the prime word in half the study and a language decision task in the other half. Within each half, there was one block in which pictures were named in L1 and one in which pictures were named in L2. Language switch was manipulated by language of the prime word, which switched randomly and unpredictably between L1 and L2. A frontal N2 was found for switch trials in the L1-L2 direction only, and switch effects were more prevalent in the semantic categorization task than the language decision task. Switch cost is discussed through the framework of two models of language control: the Inhibitory Control (IC) model and the developmental Bilingual Interactive-Activation (BIA-d) model. The results support the BIA-d model and contradict the predictions of the IC model.

Introduction

Much recent research in psycholinguistics has focused on bilingualism as a means of investigating fundamental principles of language. One question that has gathered a substantial amount of this attention is how bilinguals manage switching between their two languages. Different processing models of bilingualism have set forth a variety of explanatory frameworks of how endogenous and exogenous factors work to control which language a bilingual will use. These models share many fundamental elements; however there are several major points on which they diverge. In this study, we hope to shed further light on some of the processes responsible for language control in bilinguals.

The starting point of many of these models is the observation that representations from both languages of a bilingual are, to some degree, in a constant state of activation (Beauvillain & Grainger, 1987; van Heuven et al., 1998; Dijkstra et al., 1999; Christoffels et al., 2007; Alvarez et al., 2003). Therefore, it has been generally accepted that when bilinguals use one language, representations from the other language are necessarily subject to top-down inhibitory processes (Green, 1998; Grainger et al., 2010). However, there has been disagreement about the details of this mechanism. Language-specific selection models posit that when a bilingual is using one language, representations from the other language are completely inhibited (e.g., Costa et al., 1999). Other models assume that both languages are in constant activation to some degree, and are therefore always available for production and comprehension. In the case of these latter models, there is much evidence showing that bottom-up influences can activate both languages regardless of the context. This includes representations at the orthographic (Beauvillain & Grainger, 1987; van Heuven et al., 1998), phonological (Dijkstra et al., 1999; Christoffels et al., 2007), and semantic (Alvarez et al., 2003) levels. These studies indicate that words from a bilingual's two languages are not only constantly active, but are also stored and accessed in a very similar way.

Top-down inhibition is assumed to play a major role in bilingual processing and production (Green, 1998; Grainger et al., 2010; Kroll & Stewart, 1994). Some researchers have argued that this mechanism is a general cognitive control mechanism applied to linguistic processes (Dijkstra & van Heuven, 2002; Green, 1998). This interpretation fits well with the inhibitory control (IC) model (Green, 1998). This model argues that the switch costs observed in language switching studies reflect not only the cost of overcoming the inhibition of the incorrect language, but moreover that they reflect the cost of overcoming top-down inhibition of the prior task schema. These task schemas are the strategies people use to carry out the particular tasks demanded of them in the lab. For example, a task in which subjects must switch between categorizing words based on semantic aspects and categorizing them based on syntactic aspects will employ two different task schemas, as will language switching tasks. Switching between these two categorization schemas will produce the same cost as switching between the two languages schemas. The cost of language switching comes when bottom-up information alerts a supervisory attention system that a task schema switch is necessary. This leads the supervisory attention system to inhibit the previous task schema, which in turn inhibits representations from the incorrect language. Green (1998) argues that this inhibition acts at the level of the lemma, which refers to the uninflected, basic form of each word in the lexicon. This model assumes that switch costs reflect the specific conditions of the task subjects are asked to carry out over language switching.

An alternate model of bilingual language processing is the bilingual interactive-activation (BIA) model (Grainger et al., 2003). This model argues that mutually inhibitory language nodes exert top-down inhibition on lexical representations of the non-target language. The activation levels of these nodes is modulated by bottom-up cues and language context. Switch costs for production proceeds top-down. Due to the general higher resting activation levels of L1 representations, it costs more to inhibit L1 than L2 representations. Therefore higher switch costs are assumed for L2-L1 switches in production tasks because of the interference from the previous L1 inhibition. Switch costs in comprehension proceed bottom-up, as cues from one language activate the corresponding language node. In unbalanced bilinguals, L1 cues provide greater activation of the L1 node than L2 cues do for the L2 node, meaning there will be more interference and therefore more switch cost for L1-L2 switches in comprehension (Grainger et al., 2010).

There is some overlap between the BIA and the IC models. The BIA model posits that language nodes are responsible for modulating the activation levels of the lexical representations of each of the bilingual's languages. The IC model posits functionally equivalent language tags which are attached to each lemma and denote to which language that lemma belongs. However, one fundamental difference is that the BIA model argues that the inhibition processes involved in language selection are specific to language. The IC model states that there are two sources of inhibition which result in the interference reflected in switch costs. One source is the bottom-up inhibition which comes from language input and acts on the lexicons of the two languages. The main source of inhibition is a general top-down mechanism which modulates the activation levels of different task schemas which in turn modulate the activation of lemmas with the non-target language tag. While Green (1998) does not specify whether or not to expect asymmetrical switch cost between task schemas, it is made clear that in the IC model, overcoming the inhibition of the dominant language in unbalanced bilinguals is more costly, meaning that L2-L1 switches require more effort than L1-L2 switches.

The BIA model has recently been extended to reflect the changes that occur as late L2 learners achieve increasing levels of L2 proficiency. This developmental BIA (BIA-d) model (Grainger et al., 2010) is an adaptation of the revised hierarchical model (RHM) first proposed by Kroll & Stewart (1994). According to the BIA-d, in the early stages of L2 acquisition, L2 words access their corresponding conceptual representations via L1 translation equivalents. As L2 proficiency increases, the connections strengths of translation equivalents grow, as do the connections between L2 words and concepts. In the final stage of the BIA-d model, this link between L2 and L1 translation equivalents weakens to the point of lateral inhibition, and the link between L2 words and semantic representations becomes strong enough so that there is no need for the mediation of L1 words (see Figure 1). This last stage reflects what L2 learners report as the "magic moment" (Grainger et al., 2010, p. 276) in which use of L2 comes naturally without the help of L1. Immersion in L2 might be necessary for achieving this stage. There are several studies indicating that L2 immersion not only significantly increases proficiency in and access to L2 in production and comprehension, but it also decreases such access to L1 (Linck et al., 2009; Levy et al., 2007), perhaps reflecting the lateral inhibition between translation equivalents. This is of particular relevance to the present study because subjects had recently been immersed in a French (L2) speaking environment.

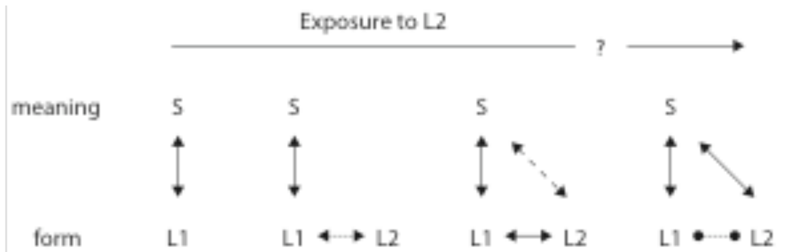

Fig. 1: The BIA-d model from Grainger et al., 2010.

Electrophysiological studies

Most of the evidence cited in favor of one or the other of these models has involved behavioral measures such as picture naming latency or number of errors in a particular task. More recently, studies using event-related potentials (ERPs) have been used to examine issues of language control. Many studies have reported finding a fronto-central negativity in language switch contexts (Jackson et al., 2001; Chauncey et al., 2008; Chauncey et al., 2009; Christoffels et al., 2007). A similar ERP effect has been demonstrated to reflect aspects of general cognitive control, including inhibition (Folstein & van Petten, 2008). Gemba and Sasaki (1989), for instance, elicited a frontoparietal N200 in response to no-go trials in a basic go/no-go button pressing task. A similar finding was reported by Falkenstein et al. (1999). These authors concluded that this N2 reflects the amount of response inhibition, since it was of greater amplitude for subjects with lower error rates. It remains possible that the fronto-central negativity seen in language switching contexts is related to the N2 seen in situations of response inhibition.

There is ample evidence that proficiency in L2 affects switch costs. Costa and Santesteban (2004), for instance, found that the longer naming latency to switch trials in a picture naming task was only present for less proficient L2 learners. Midgley et al. (2008) reported that more proficient L2 speakers show a larger posterior N400 in response to L2 critical trials in an unprimed semantic categorization task blocked by language. Also, for the same trials, less proficient L2 speakers showed more of a latency shift (of roughly 50-100ms) of the N400. The authors interpret the latency shift to reflect the extra time it takes for L2 words to access translation equivalents before accessing semantic representations.

This type of latency shift to L2 targets was also reported by Chauncey et al. in a production task (2009) where their subjects were asked to name pictures in a task blocked by language. Pictures, presented for 300ms, were preceded by masked primes of 70ms duration which were either in the subjects' L1 or L2. Primes were either the name of the following picture, or the name of a different, unrelated picture. Language switch was manipulated by the language of the prime, and ERPs were time-locked to the picture onset. In the 200-300ms time window, a negativity was found for switch trials with unrelated primes in L1-L2 prime-target pairs, but not with L2-L1 pairs. This asymmetrical switch cost was interpreted as reflecting that in L1-L2 trials, the L1 prime interfered with the inhibition of L1 representations necessary for L2 production. The authors also suggest that the lack of negativity in L2-L1 trials in this early window reflects the longer amount of time it takes for L2 words to access semantic representations. A later asymmetrical switch effect was found as well, with L1-L2 trials producing more positivity at posterior and central sites and more negativity at anterior sites of the right-hemisphere. This was interpreted as reflecting the effects of aspects of the structural representations of the pictures as well as their associated amodal semantic representations.

The current study

The design of the present study is similar to that of Chauncey et al. (2009). Subjects in the current study named primed pictures in language blocks. The main difference is that the word primes are not masked and are of longer duration (1500ms) which allows them to be actively attended to. In half of the study subjects perform a language decision task on the prime and in the other half they perform a semantic categorization task. Language of the prime switches between French and English unpredictably, although the picture targets are named in one language in one block and the other language in a second block. Since primes are consciously attended to, we expect our study to reveal more robust language switching effects than that of Chauncey et al. (2009), where primes were masked and of short duration.

If the BIA-d model is correct, we would expect switch cost asymmetry to reflect aspects of non-target language inhibition and between language interference. Comprehension of a prime word in one language will cause inhibition of representations in the other language. This will likely be an especially strong effect for L1 prime words, as it is argued that comprehension of L1 words produces more bottom-up activation of the corresponding language node than do L2 words (Grainger et al., 2010). Naming pictures in one language requires top-down inhibition of words from the opposite language. This inhibition will be stronger in the case of L2 production compared to L1 production. Therefore, the BIA-d model predicts that switch costs in the ERP data will be larger for L1-L2 trials than for L2-L1 trials, as the former trials will be subject to more between language interference as well as within-language inhibition.

However, if the IC model is correct, we should see similar ERP data in the early (200-300ms) window in both switch and non-switch trials. Both types of trials include switching between two tasks: language decision or semantic categorization switches with picture naming. Following the IC model, the same top-down executive inhibition of task schemas used for language switching should be used for task switching as well , since both will require the supervisory attention system to alter levels of inhibition of different task schemas in order to carry out the appropriate switch (Green, 1998). The task switching costs predicted for early ERP data should be amplified in switch trials, as language switching will produce bottom-up interference of successful inhibition of the non-target language. In these trials, the IC model predicts a higher switch cost for L2-L1 than for L1-L2 switches. If the IC model is correct, the results of the present study should uncouple the effects of top-down task schema inhibition from the bottom-up effects of language switching.

The IC model will also predict a larger switch cost associated with trials in the language decision task compared to those in the semantic categorization task. In the language decision task, language information is consciously attended to. The IC model should predict that task schemas operating in this task will therefore produce more top-down inhibition of the incorrect language. On the other hand, the task schema involved in the semantic categorization task should not need to take into account language information, so it will not produce any top-down inhibition. Switch trials in both tasks, however, will be subject to bottom-up inhibition from the prime word.

Method

Subjects

Subjects (n= 13 [11 female], average age 20.7) were all Tufts University undergraduates, recruited from an online posting and word of mouth. All subjects were right handed, native English speakers, late learners of French (average age of exposure: 12.8) who had been immersed in a French speaking environment for an extended period of time within the last year (average length of immersion: 5.1 months), except for one subject who spent 10 months in France 2 years before the study. Only one subject had ever learned any other language besides English and French (this subject had recently taken one semester of university German). Subjects were asked to evaluate their degree of bilingualism on a scale of 1 to 9, 1 meaning "I speak only French," 9 meaning "I speak only English," and 5 meaning "I speak both French and English." The average reported level of bilingualism was 6.3. Subjects were asked to wear glasses instead of contacts on the day of the study if they had corrected vision to reduce the frequency of blinking interfering with the data.

Design and Stimuli

The study was divided into four blocks. There were two separate tasks consisting of two blocks each: a semantic categorization task and a language decision task. All blocks consisted of fifty images shown twice, once preceded by a French word and once preceded by an English word. Semantic categorization blocks also had ten extra non-critical images preceded by animal names in either French or English. Upon recognizing an animal name, subjects pressed a button with their right thumb. In the language decision task, subjects pressed one button for words in English and another button for words in French. Half of the subjects pressed for English with their left finger and French with their right, and the other half did the reverse. Both tasks were done twice by all subjects, one block with English as the picture-naming language and one block with French as the picture-naming language. All images were named twice in all blocks, once preceded by an English word, and once by a French word. Language switching was manipulated by the language of the preceding word versus the picture-naming language of the block. Blocks were randomized for each subject and were constructed so that there were at least 25 trials between the two presentations of every image. There were four versions of each specific block with different word primes and different image presentation orders of which every subject saw one. These were used in a counterbalanced order.

ERPs were time-locked to the onset of the image. A previous study by Chauncey et al. (2009) indicated that articulatory artifacts in picture naming tasks do not affect the ERPs in the initial 700 ms after stimulus presentation, which is a large enough window to see the anticipated results.

The critical words in this study were all between 4 and 6 letters in length. They were matched between block on lemma frequency and word length. They were also matched so that the two words preceding any given picture within one block had the same word length and a very close lemma frequency.

Procedure

After signing a consent form, each subject was seated in a comfortable chair as experimenters attached electrodes to the face and placed an electrode cap on the head. Once set up was completed, subjects were fitted with a headset microphone to be used during the study to record responses and naming latencies. The microphone was tested before the study began by recording subjects speaking into it and replaying it to ensure it was working properly. Next, subjects were familiarized with all 50 critical images used in the study as well as the ten images used in practice trials and the ten non-critical images that follow the animal words in the semantic categorization task. This was done by presenting the images one at a time with the corresponding name in print above the image. This was repeated four times using four randomized blocks, with two blocks in French and two in English. Next, subjects were tested on the picture names by scrolling through a randomized block of all images two times, naming them all in English in one block, and all in French in the other block. If a subject made a mistake naming a picture, the experimenter told him or her the correct word to say. Finally, there was a practice session before each block consisting of 10 trials which familiarized the subjects with the task as well as the language in which to name the picture. These 10 images used in the practice session were not included in the critical blocks.

In all four critical blocks of the study, trials started with a fixation cross in the center of the screen for 200ms followed by a 100ms blank screen. Next, subjects saw a printed word (in courier font) for 1500ms followed by a 500ms blank screen. The critical image was presented next for 4000ms, directly after which was a 1500ms blink symbol marking the end of the trial (see Figure 2). Subjects were asked to try not to blink during the study until they saw the blink stimulus, as blinking creates much electrical activity that interferes with the data we were looking for. Similarly, subjects were asked to get comfortable before the study began and to refrain from moving unnecessarily during each block. All blocks of the study had three breaks in which subjects could rest and return to the task at their own pace. After the first two blocks (when switching from the first to the second task), subjects were allowed to take a longer break. After all four blocks had been run, the electrode cap and face electrodes were removed and subjects were asked to fill out a 50 word translation page, translating both directions (i.e., L1-L2 & L2-L1). This translation page consisted of words of low, medium, and high frequency (based on the frequency of the L2 word being translated into or from) and were graded accordingly using a log function. Finally, subjects were paid.

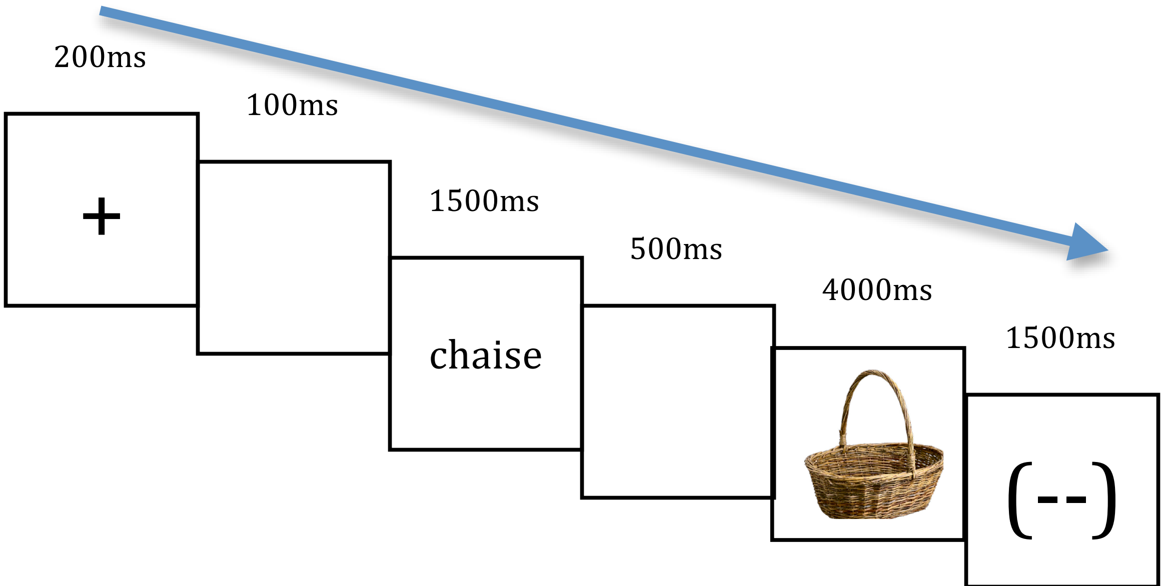

Fig. 2: The time-course of a typical trial.

EEG Procedure

All subjects were run at the Neurocognition Lab at Tufts University. Subjects were seated in a comfortable chair in a dimly lit, sound attenuated room. Stimuli were presented on a 19 inch monitor placed approximately one meter away from the subjects. ERPs were time-locked to the onset of target images. Subjects were fitted with a cap containing 29 electrodes. Two other electrodes were attached around the eyes to monitor for blinks as well as horizontal and vertical eye movements. All electrodes were referenced to an electrode attached to the left mastoid bone. Another electrode was attached to the right mastoid bone to monitor for asymmetry in the mastoid signals (see Figure 3). All 32 channels were amplified by an SA

Bioamplifier with a bandpass of .01 and 40Hz and a continuous sample rate of 200Hz. Impedances were under 5kΩ for all cap electrodes, under 10kΩ for the eye electrodes and under 2kΩ for the mastoid electrodes.

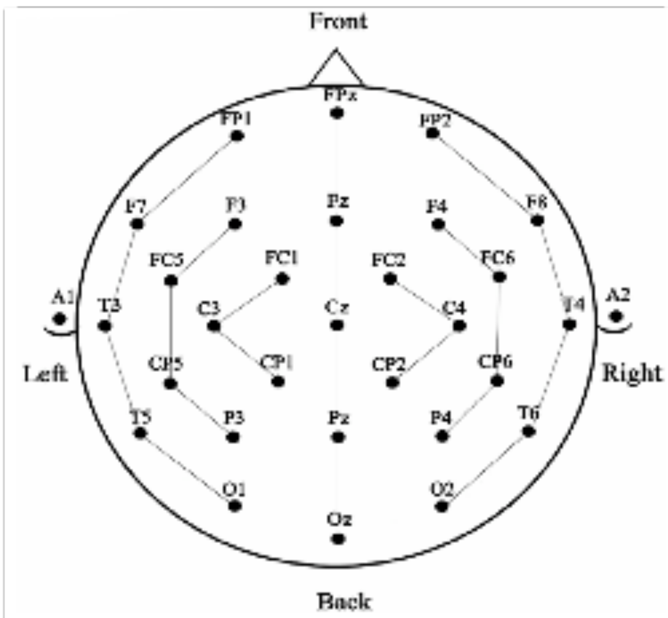

Fig. 3: The scalp distribution of the electrodes used in this study.

Data Analysis

Trials with blinks, eye movements, or artifacts within 600ms of target picture onset were rejected prior to averaging the ERP data. Separate analyses were used for both language blocks of both tasks. Analyses were calculated relative to the time window of the first 50ms post target picture onset. ERP data were measured by calculating the mean amplitude between upper and lower latencies. The electrodes analyzed distributed across a broad midline from anterior to posterior (Fp1, Fpz, Fp2, F3, Fz, F4, C3, Cz, C4, P3, Pz, P4, O1, Oz & O2). Windows of analysis were divided into the time windows of 200-300ms, 300-400ms, and 400-500ms post target image onset.

Results

ERP Results

Figures 4 and 5 show ERPs time locked to the to-be-named images from the language decision task in English and French, respectively. Figures 6 and 7 show ERPs time locked to critical images from the semantic categorization task in English and French, respectively. An omnibus analysis (See Figure 8) of the effects of switch trials compared to non-switch trials was carried out for both language blocks of both tasks in the time windows of 200-300ms, 300-400ms, and 400-500ms.

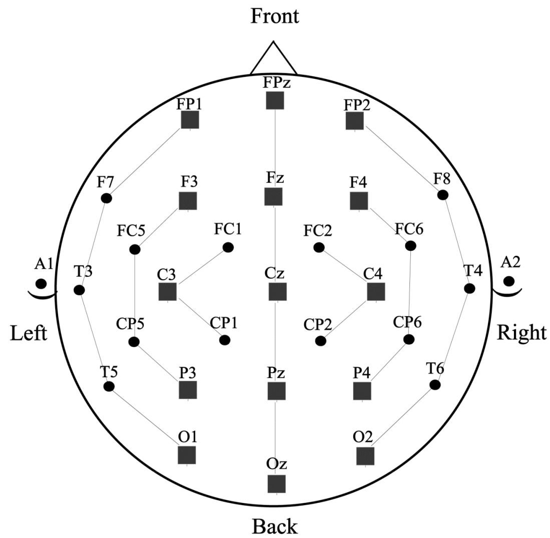

Fig. 8: The scalp distribution of the 15 electrodes analyzed in the omnibus ANOVA. Analyzed electrodes appear as squares.

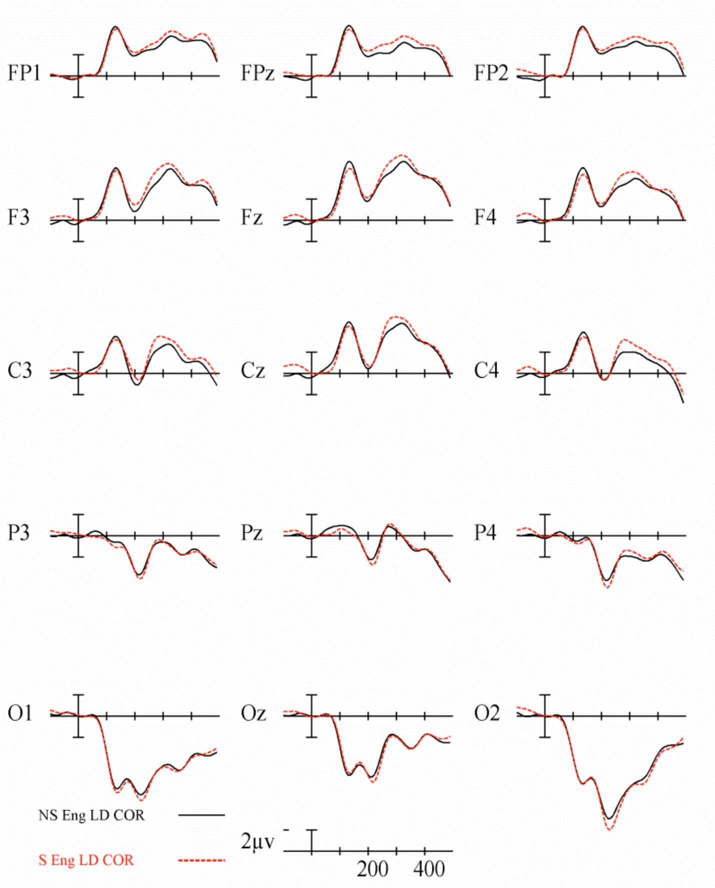

Fig. 4: ERPs from 15 scalp sites time-locked to picture onset in the language decision task. Pictures were named in English (L1), and preceded by either English primes (solid black line) or French primes (L2) (dotted red line).

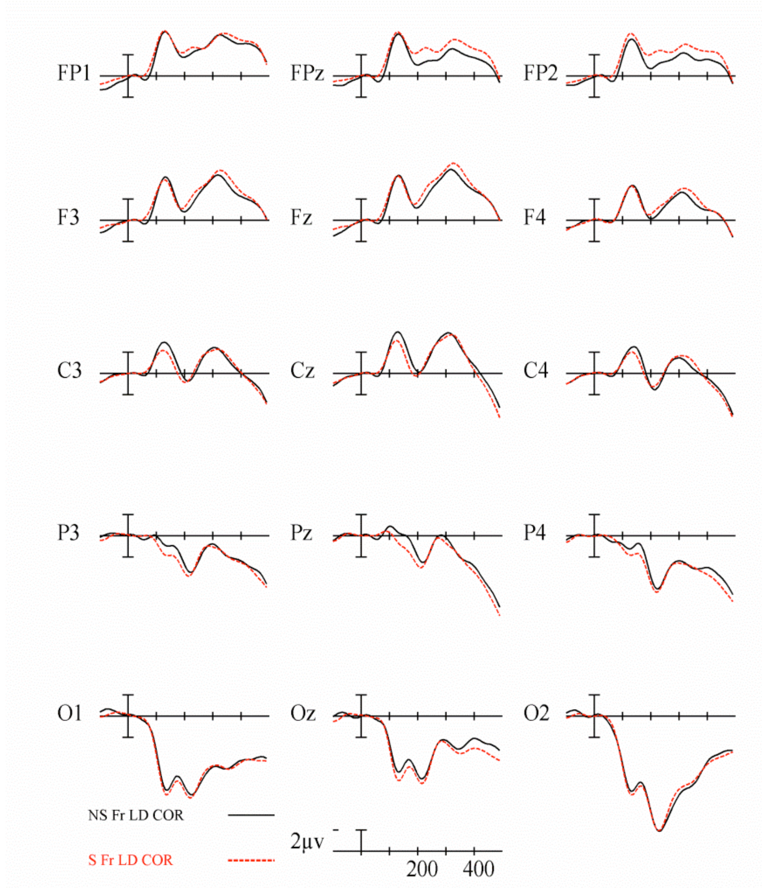

Fig. 5: ERPs from 15 scalp sites time-locked to picture onset in the language decision task. Pictures were named in French (L2), and preceded by either French primes (solid black line) or English (L1) primes (dotted red line).

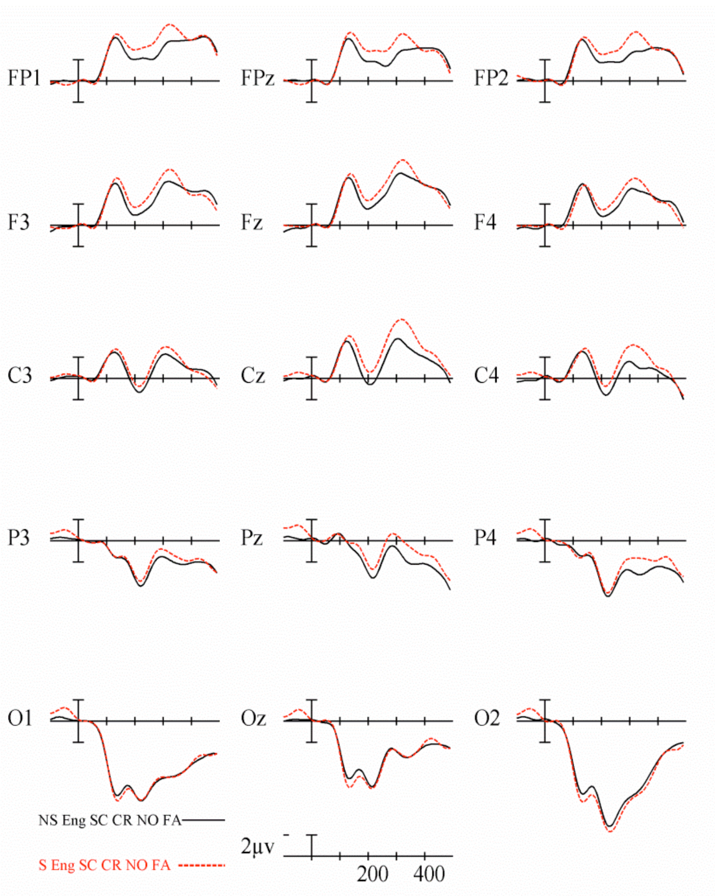

Fig. 6: ERPs from 15 scalp sites time-locked to picture onset in the semantic categorization task. Pictures were named in English (L1), and preceded by either English primes (solid black line) or French (L2) primes (dotted red line).

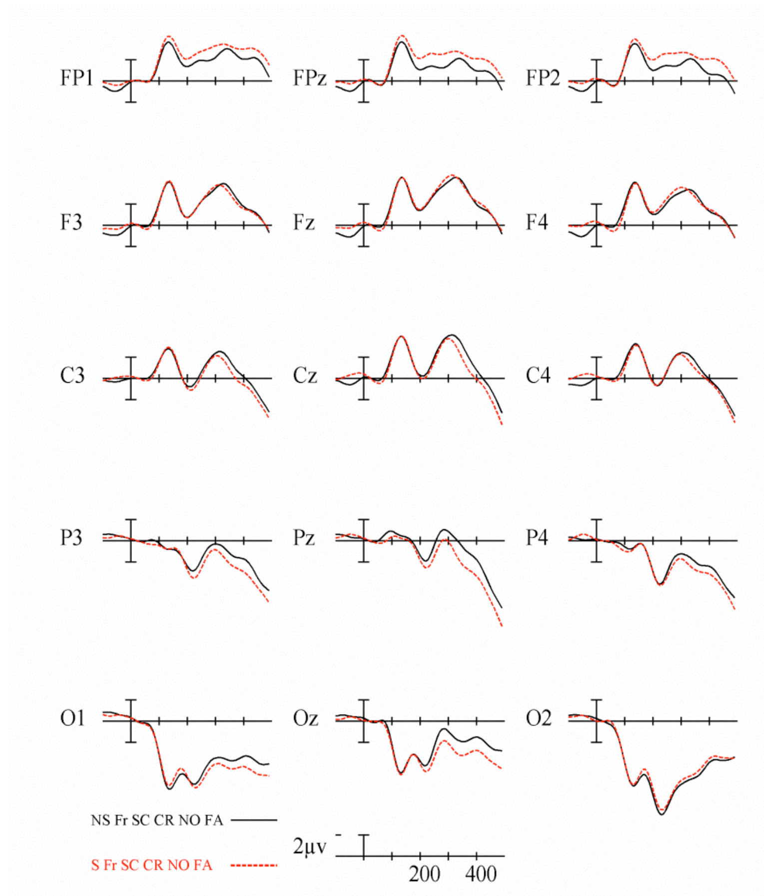

Fig. 7: ERPs from 15 scalp sites time-locked to picture onset in the semantic categorization task. Pictures were named in French (L2), and preceded by either French primes (solid black line) or English (L1) primes (dotted red line).

200-300ms

In this epoch, the English picture-naming block of the language decision task revealed significant interaction of switching x anterior-posterior ($F= 3.49$, $p= 0.0434$). The French picture-naming block of this task revealed no significant effects of switching. In the semantic categorization task, the French picture-naming block revealed a significant interaction of switching x anterior-posterior ($F= 9.16$, $p= 0.0006$). English picture-naming block of this task produced no significant effects of switching.

300-400ms

This epoch yielded no significant effects of switching for the language decision task in either picture-naming language. In the semantic categorization task, the English picture-naming task revealed no significant effects of switching. However, in the French block of this task there was a significant interaction of switching x anterior-posterior ($F= 5.23$, $p= 0.0142$), as well as trends towards significant effects of switching x laterality ($F= 3.08$, $p= 0.0872$).

400-500ms

In this epoch, there were no significant effects of language or switching in the language decision task for either picture-naming language, nor were there any such effects in the English picture-naming block of the semantic categorization task. However, the French picture naming block of the semantic categorization task revealed a significant interaction of switching x anterior-posterior (F= 7.66, p= 0.0017).

Follow-up Analysis

A follow-up analysis was carried out to further investigate the effects of language switching. This analysis focused on a negativity that was observed during visual inspection of the ERP data. This negativity starts around 200ms and peaks around 300-325ms at two anterior electrode sites: Fpz and Fp2 (See Figure 13). An ANOVA was carried out for these sites contrasting switch and non-switch trials in both blocks of each task in the 200-400ms time window. Resulting voltage maps are shown in Figure 14. In both language blocks of both tasks, switch trials produced more negative-going waveforms than non-switch trials in this epoch. For the language decision task, this ERP difference was not significant for the English picture-naming block (See Figure 9). However, this effect was significant in the French picture-naming block of this task (F= 5.48, p= 0.0373) (See Figure 10). Similarly, in the semantic categorization block, the English picture-naming task did not produce significant effects of switching (See Figure 11), but the French picture-naming block did elicit significant switch effects (F= 7.48, p= 0.0194) (See Figure 12).

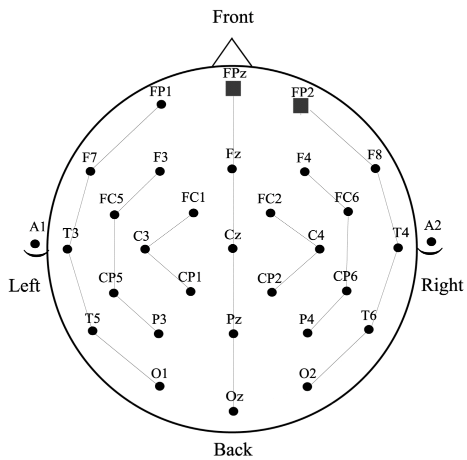

Fig. 13: The two electrode sites analyzed in the follow-up ANOVA. Analyzed electrodes appear as squares.

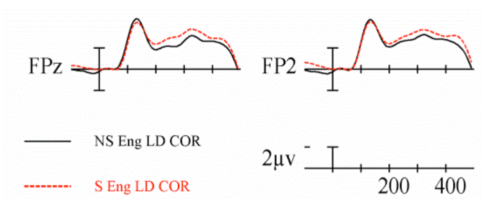

Fig. 9: ERPs from the two scalp sites analyzed in the follow-up analysis of the language decision task. Pictures were named in English (L1) and were preceded by either English primes (solid black line) or French (L2) primes (dotted red line).

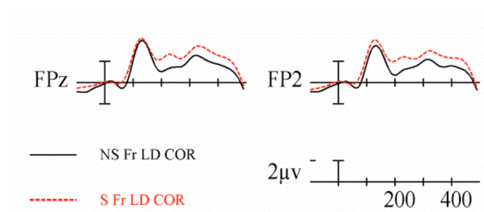

Fig. 10: ERPs from the two scalp sites analyzed in the follow-up analysis of the language decision task. Pictures were named in French (L2) and were preceded by either French primes (solid black line) or English (L1) primes (dotted red line).

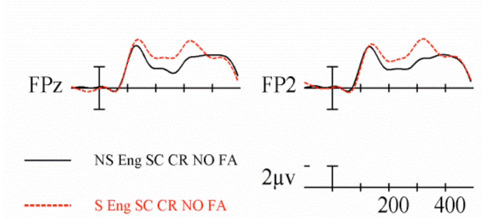

Fig. 11: ERPs from the two scalp sites analyzed in the follow-up analysis of the semantic categorization task. Pictures were named in English (L1) and were preceded by either English primes (solid black line) or French (L2) primes (dotted red line).

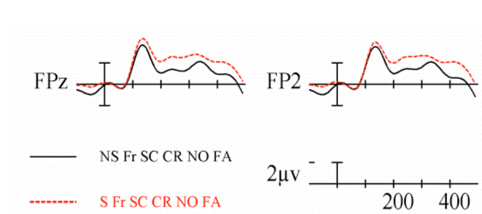

Fig. 12: ERPs from the two scalp sites analyzed in the follow-up analysis of the semantic categorization task. Pictures were named in French (L2) and were preceded by either French primes (solid black line) or English (L1) primes (dotted red line).

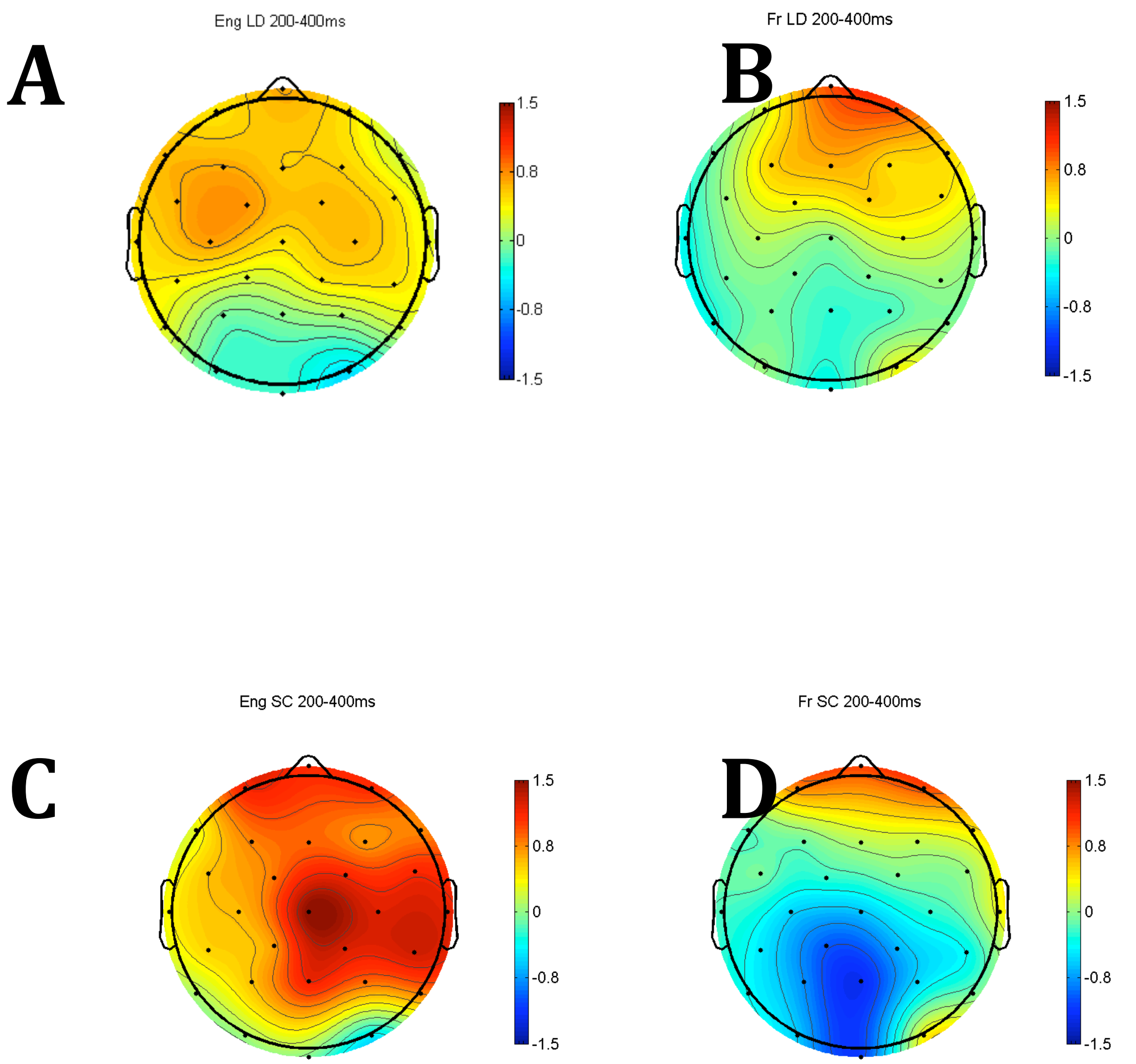

Fig. 14: Voltage maps computed by subtracting the average voltages of switch trials from non-switch trials in the 200-400ms time window from 29 scalp sites in the following conditions: (A) The English picture-naming block language decision task. (B) The French picture-naming block of the language decision block. (C) The English picture-naming block of the semantic categorization task. (D) The French picture-naming block of the semantic categorization task

Summary of ERP results

The omnibus ANOVA revealed that the semantic categorization task produced interactions between switching and scalp distribution in all three time windows analyzed for the French (L2) picture-naming block. This effect was not present for the English picture-naming block of this task. ANOVA revealed no effects or interactions of switching in the language decision task. A follow-up ANOVA analyzed the effects of switching in the 200-400ms epoch for both picture-naming blocks for both tasks at a restricted set of electrode sites (Fpz and Fp2). In both tasks, switch trials produced more negative-going waveforms. However, these negativities only reached significance in the French picture-naming blocks of each task.

Discussion

The present study explored the effects of language switching on ERP data in a primed picture-naming task. The study was designed to determine which theoretical model more accurately describes language processes in bilinguals: the Inhibitory Control (IC) model, or the developmental Bilingual Interactive-Activation (BIA-d) model. The results of the present study reveal two main findings of interest. The first is that L1-L2 switch trials are associated with a frontal negativity compared to L2-L2 trials regardless of task. Visual inspection of the ERP waveforms indicates that this effect is marginally present, though not significant, in L2-L1 trials when contrasted with L1-L1 trials. In both picture-naming language blocks these waveforms begin to differentiate at around 200ms post target picture onset. Next, the omnibus ANOVA revealed significant effects of switching in the semantic categorization task for every time window, whereas these effects were only seen in the language decision task in the 200-300ms time window.

Language switching involves inhibition of the non-target language (Green, 1998; Grainger et al., 2010), and the frontal negativities observed for certain switch trials appear in similar brain regions and time ranges as those reported in studies investigating response inhibition. Falkenstein et al. (1999), for instance, report a frontal N2 in response to no-go trials in a visual go/no-go task. This effect started around 200ms, peaking around 300ms. A study by Schmitt et al. (2001) found a frontal negativity in response to no-go trials in a dual choice go/no-go task. When subjects were asked to attend to semantic aspects of the picture names, the mean onset latency of this negativity was 255ms post target onset and the mean peak latency was 384ms post target onset. These negativities are similar to those found in the present study in both timing and location, indicating that the present negativities likely belong to this same family of N2-like effects. If this characterization is correct, then it seems reasonable to conclude that these effects reflect the process associated with response inhibition. This conclusion leads us to revisit the predictions of the IC model.

The IC model posits that the inhibition mechanism used in language switching is the same mechanism used for non-linguistic tasks (Green, 1998). This model predicts several ERP differences as a function of task and the direction of language switch. According to the IC model, the language decision task should involve conscious consideration of language in the task schema being employed. This should mean that there will be top-down inhibition of the incorrect language upon detection of the presented language. The task schema used for the semantic categorization task, however, does not necessitate this level of conscious awareness of the prime language in order to accomplish the task. In both tasks, primes will produce bottom-up inhibition of the opposite language. However, it is only in the language decision task that the IC model predicts top-down inhibition as well. The prediction that follows is that the switch cost in the language decision task should be greater than that in the semantic categorization task. The results of the present study do not support this prediction. The omnibus ANOVA revealed that effects of switch were found almost exclusively in the semantic categorization task. Further, the follow-up ANOVA revealed that the statistically significant switch costs were more significant in the semantic categorization task than they were in the language decision task, as evidenced by the frontal negativity.

The results of the present study reveal that L1-L2 trials produced more frontal negativity than L2-L1 trials relative to non-switch trials in the respective language blocks, regardless of task. The IC model predicts higher switch cost for L2-L1 trials compared to L1-L2 trials (Green, 1998). The predictions of the IC model about task and direction of language switch would therefore seem to be contradicted by the current results.

The BIA-d model posits that comprehension of L1 words leads to more activation of the L1 language node than L2 words do for the L2 node. This means that L1 primes will have more of an effect on target processing than L2 primes in the present study, as the prime task involves comprehension, not production. The BIA-d model also posits that L2 production requires stronger inhibition of L1 words than vice versa (Grainger et al., 2010). Therefore, the BIA-d model predicts that in the present study, L1-L2 prime target pairs will produce the most between-language interference as well as the most within-language inhibition. This means L1-L2 trials will be subject to more switch cost than L2-L1 trials. This fits well with the results of the present study, as the follow-up analysis revealed that L1-L2 trials produced significant negativities compared to L2-L2 trials, and L2-L1 trials produced only marginal negativities compared to L1-L1 trials. Therefore, the results of the present study support the BIA-d model.

The second main finding of interest is the greater ERP effects of language switching in the semantic categorization task than in the language decision task. The omnibus ANOVA showed switching effects in all three time windows for the semantic categorization task and the lack of such effects in all but one of the time windows of the language decision task. Follow-up analysis also revealed that the L1-L2 switch costs were slightly more significant in the semantic categorization task than in the language decision task. The former task requires conscious analysis at the semantic level, meaning that the bottom-up influence of the prime word likely results in a high degree of language-node activation. The language decision task requires less analysis of the prime word because processing of the prime might not need to exceed the orthographic level of representation in order to accomplish the task. Moreover because prime words were not controlled for language-specific orthographies, it might have been possible for subjects to make their language decisions on these kinds of low-level orthographic cues, thus not requiring much activation of corresponding language nodes. Therefore, it is possible that the larger prime effects in the semantic categorization task reflect the higher degree of language node activation for this task over the language decision task.

Conclusion

The present study examined language switching in a primed picture-naming task. The results of the present study empirically support the developmental bilingual interactive activation model (BIA-d) of language switching. Analysis of two frontal sites in the 200-400ms epoch revealed that switch costs were only significant in the L1-L2 direction. It is suggested that this was due to the high amount of interference from the L1 prime as well as the high amount of inhibition necessary for L2 production upon target picture presentation. The second significant finding is that the semantic categorization task produces more priming effects in language switch trials than does the language decision task. Further research is necessary to explore the possible connection between the N2 found in language switching and that found in response inhibition. Also, it would be valuable to investigate how switch effects change with growing L2 proficiency as a means of testing the developmental timeline of the BIA-d model.

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