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Intraoperative electrical stimulation of language switching in two bilingual patients

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ABSTRACT

Background: Language switching (LS) is an important phenomena usually observed in some bilingual communities. The ability to switch languages is a very fast, efficient and flexible process, being a fundamental aspect of bilingual efficient language communication. The aim of the present study was to characterize the specific role of non-language specific prefrontal regions in the neural network involved in LS in bilingual patients, during awake brain surgery and using electrical stimulation mapping (ESM).
Methods: In order to identify the neural regions involved in LS we used, a new specific ESM protocol in two patients undergoing awake brain surgery. Besides, functional magnetic resonance imaging (fMRI), neuropsychological testing and the assessment of daily conversational LS patterns post-surgery were used as complementary imaging and behavioral assessments.
Results: The outcome of the multimodal ESM-fMRI neuroimaging comparison in both patients pointed out to the crucial involvement of the inferior and middle frontal cortices in LS.
Conclusions: The present results add to previous findings highlighting the important role of non-language specific frontal structures in regulating LS. The new protocol developed here might allow neurosurgeons to plan ahead for surgical intervention in multilingual patients to ensure the preservation of regions involved in LS and therefore the prevention of pathological language mixing after intervention.

1. Introduction

Language switching (LS) is a very fast, efficient and flexible process that occurs when bilinguals alternate between two languages in the same conversation (Bialystok, Craik, Green, & Gollan, 2009; Penfield & Roberts, 1959). Importantly, LS supports effective communication in bilingual environments by enabling individuals to appropriately select the language spoken as a function of external cues such as linguistic knowledge of their interlocutor, face-related cues or contextual effects (Festman, 2012; Rodriguez-Fornells, Kramer, Lorenzo-Seva, Festman, & Münte, 2011; Soveri, Rodriguez-Fornells, & Laine, 2011). When this ability is impaired and the language in use becomes inappropriate to the external contexts, LS can be considered pathological (Fabbro, Skrap, & Aglioti, 2000; Paradis, 1995, 2012).

Clear anatomical evidence supporting the existence of LS has not yet been established, although several studies have pointed out to the possible involvement of the middle frontal gyrus (MFG) and the inferior frontal gyrus (IFG) (see Abutalebi & Green, 2007; Hervais-Adelman, Moser-Mercer, & Golestani, 2011; Rodríguez-Fornells, de Diego Balaguer, & Münte, 2006; Luk, Green, Abutalebi, & Grady, 2012 for a review). For example, Fabbro et al. (2000) described a bilingual case of pathological LS with a lesion encompassing the left prefrontal cortex affecting the underlying white matter of the IFG, the MFG and the superior frontal gyri [including the left anterior cingulate cortex (ACC) and the anterior callosal fibbers]. This patient, who did not show aphasic symptoms in any of his two languages, pathologically switched between them despite the instruction to speak in a particular language even at times when the patient was aware of the switches introduced. The lesions in the ACC, prefrontal cortex and the underlying white-matter lesions could have affected this patient in his ability to

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maintain the goal of the communication (e.g., which is the language in use?) or the ability to suppress the interference from the other non-used language. Similarly, it has been shown that transcranial magnetic stimulation (TMS) applied to the MFG (more precisely to the left dorsolateral prefrontal cortex—DLPFC) can induce involuntary LS (Holtzheimer, Fawaz, Wilson, & Avery, 2005). Moreover, a lesion study of a patient who suffered an ischemic stroke in the aforementioned structure (DLPFC) and presented pathological switching further supports the importance of this region in LS (Nardone et al., 2011).

In line with these findings, an enhanced activation in the posterior inferior frontal region has also been revealed in an fMRI study using an LS-related task in bilinguals (Rodriguez-Fornells, Rotte, Heinze, Nosselt, & Münte, 2002). It has been proposed that the DLPFC probably mediates cognitive control in bilinguals through the interplay between a top-down selection–suppression mechanism and a local inhibitory mechanism in charge of reducing the activation of the non-target language (Rodríguez-Fornells et al., 2006). Similar activations in cognitive control prefrontal regions such as the ACC (and supplementary motor area, SMA), left middle prefrontal cortex and in the left portions of the IFG have also been reported in other fMRI studies in language switching contexts (Abutalebi et al., 2007; Guo, Liu, Misra, & Kroll, 2011; Hernandez, Martinez, & Kohnert, 2000; Rodriguez-Fornells et al., 2005). Even in monolingual language settings, bilinguals tend to largely activate several regions in the left prefrontal and inferior frontal cortex, being these activations most probably related to the control of interference or efficient suppression of the language not in use (Green & Abutalebi, in press; Kovelman, Baker, & Petitto, 2008; Parker Jones et al., 2012; Rodríguez-Fornells et al., 2006).

Furthermore, an electrical stimulation mapping (ESM) study conducted by Kho et al. (2007) showed that a temporary disruption of the IFG may provoke an involuntary language switch. A similar effect has been recently encountered while stimulating the DLPFC in a trilingual patient (Lubrano, Prod´homme, Demonet, & Kopke, 2012). Lastly, the ESM study of Moritz-Gasser & Duffau (2009) revealed that electrical stimulation applied to the posterior part of the superior temporal sulcus or the tumoral resection at the level of the superior longitudinal fasciculus (SLF) can each elicit involuntary LS. Interestingly, the SLF connects the posterior part of the temporal sulcus with the IFG, which pinpoints the possible role of this white matter tract in LS. It is worth mentioning that the same ESM technique has been used previously to characterize overlapping as well as specific neural representations of the different languages in bilinguals (Lucas, McKhann, & Ojemann, 2004; Roux & Trémoulet, 2002; Roux et al., 2004). In summary, the present evidence supports the idea that the left middle and inferior frontal cortices play a crucial role in LS.

The aim of the present study was to investigate the specific role of the middle and inferior frontal regions in LS in two Spanish-Catalan bilingual patients using for the first time complementary ESM, fMRI and neuropsychological assessment. With that purpose in mind we developed a new LS-ESM paradigm that allows systematic evaluation of externally triggered LS (see Fig. 1a). Until now, LS-specific sites have been reported in ESM studies for involuntary LS during object naming and mostly at the moment of tumor resection (Kho et al., 2007; Lubrano et al., 2012; Moritz-Gasser & Duffau, 2009). The novelty of the present study relies on the development of a specific method that permits the control of voluntary switching using ESM in a cued-LS task before the resection. This new protocol might allow neurosurgeons to plan ahead of surgical intervention in multilingual patients to ensure the preservation not only of naming sites but also of regions involved in LS. This aspect is important for the possible prevention of pervasive and involuntary language switching after surgery, as observed in the first patient described in the present study.

2. Methods

2.1. Participants

Patient 1 was a 60-year old, right-handed male, diagnosed as having anaplasic astrocytoma located in the left hemisphere (Fig. 2a). The fronto-opercular tumoral lesion he suffered was provoking epileptic seizures followed by periods of post-ictalaphasia. In the pre-surgery fMRI study, the language lateralization of Patient 1 was considered as predominantly left. Patient 1 had Catalan as his first language (L1), however, he had received formal education in Spanish (L2), and thus, had a similar level of proficiency in both languages (Table 1).

Patient 2 was a 36-year old, right-handed male, suffering from multiple cephalalgias and had complained of occasional word finding difficulties associated with tiredness or stress for 6 months prior to the diagnosis of glioblastoma (see Fig. 3a). The tumour was localized at the temporal lobe of the left hemisphere,

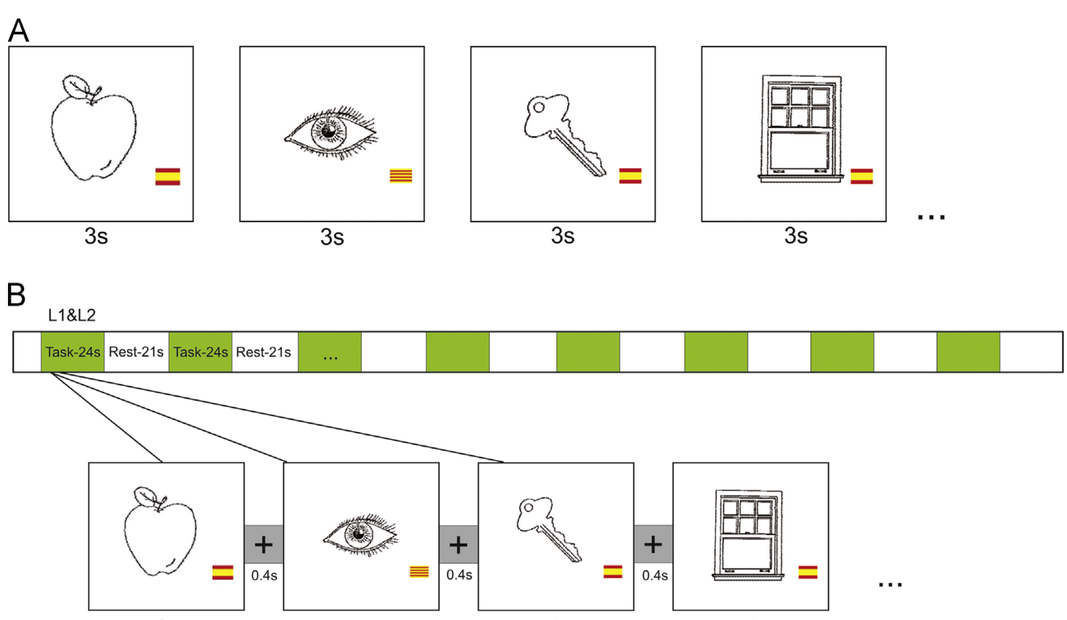

Fig. 1. (A) Example of stimuli for experimental LS naming during the ESM. Duration of single image presentation is 3 s. (B) Block-design for the fMRI procedure on LS naming. Duration of single image presentation is 2 s followed by 0.4 s of fixation point. Each trial is composed of 10 images followed by 21 s of rest. The task is made up of a total of 16 blocks (8 of active tasks and 8 of rest).