Brain correlates of language membership processing in the bilingual brain: an fMRI study

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Introduction:

The Bilingual Interactive activation model (BIA, Dijkstra, 2007; Grainger and Dijkstra, 1992) is a model for bilingual word recognition that consists of four levels of representations, corresponding to letter features, letters, words and language membership. It assumes that the mental lexicon of bilinguals is integrated and it does not initially make any distinction between words in L1 and L2 (i.e. language non-selective access).
In this model, language membership information becomes active only after lexical candidates have been activated, and it plays a key role in distinguishing between words in the two languages.
An fMRI experiment was carried out to ascertain the neural basis of language membership information during bilingual lexical access. In order to isolate this processing stage, we compared brain activations under Lexical decision (LXD) and Language decision (LGD) conditions in a proficient bilingual (Catalan-Spanish) sample.

Methods:

Subjects:
Eighteen right-handed Spanish-Catalan bilinguals (9 females and 9 males) aged between 18-25 years old (M = 20, 94) were recruited. All the participants began to speak Catalan (M = 2, SD = 1, 87) and Spanish (M = 2, SD = 3, 47) before the age of 6.
Task:
A block design task was performed with three different conditions: control, language decision (Spanish vs. Catalan words) and lexical decision (words vs. non-words). The task lasted for 10.45 min of alternating control and lexical and language conditions (10 blocks of each condition).
MRI Acquisition:
MR images were collected using a Siemens Avanto 1.5T scanner (Siemens, Erlangen, DE). 258 continuous EPI functional volumes were collected (TR/TE = 2500/30 ms, flip angle = 90, 38 axial slices, matrix = 64×64, thickness/gap = 3/0.5 mm, voxel size = 3.5×3.5×3.5). Before the functional MR sequence, an anatomical 3D volume was acquired using a T1-weighted gradient echo pulse sequence (TR/TE = 11/4.9 ms; DFOV = 23.2×26.4 cm; matrix = 256×224×176; voxel size = 1×1×1).
Imaging data analysis:
Image preprocessing using SPM5 consisted of head motion correction, spatial normalization to the MNI coordinates (3 mm3) and spatial smoothing (FWHM = 6 mm3). The General Lineal Model was then applied for statistical analysis. A paired t-test was performed for comparison between conditions.

Results:

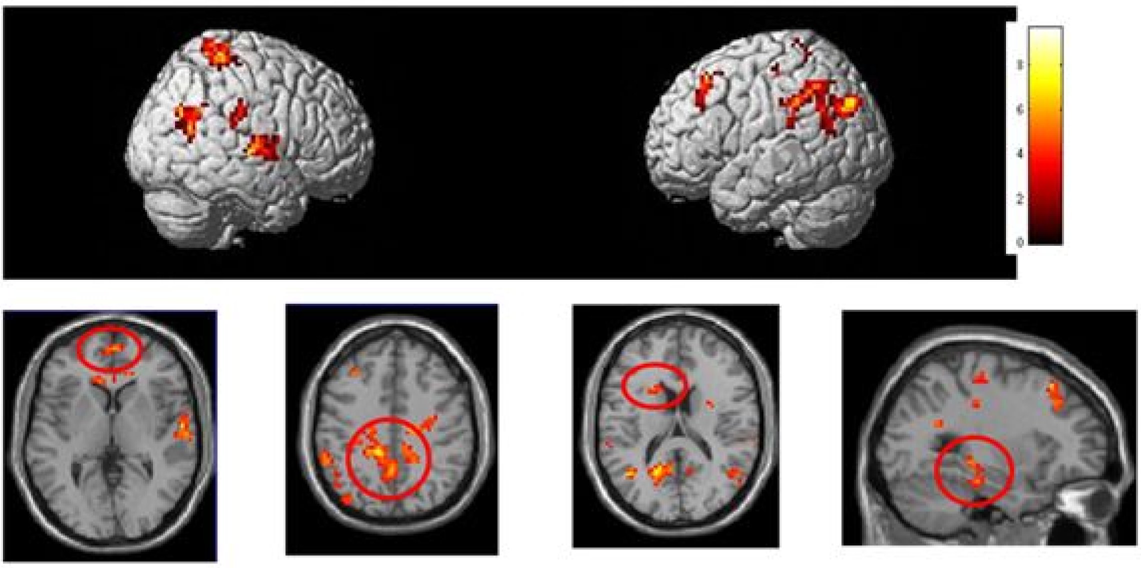
Behavioral data
No significant differences were found in the RTs between the words of the LXD and LGD conditions.
fMRI data
Comparison between groups
When we compared the brain networks obtained for the LGD and LXD, we observed significant differences ($p<0.001$, corrected at cluster level $p<0.05$, $k = 24$). The LGD showed greater activation than the LXD (see figure 1) in the left caudate, the anterior cingulate and the right superior and middle temporal gyri, as well as in the inferior parietal lobe, the supramarginal and angular gyri bilaterally. Activation was also detected in the posterior cingulate and precuneus,

the left hippocampus and parahippocampal gyrus and the left medial frontal gyrus. By contrast, no significant differences were observed in the opposite comparison.

Conclusions:

fMRI data showed a network of activation for LGD which was stronger than that of LXD, and might account for language membership processing. The relevant areas were located in the left caudate and dorsolateral prefrontal cortex, areas involved in language control processes (Abutalebi, 2008; Crinion et al, 2006) and classically related to cognitive control (Braver & Barch, 2006). Activation was also found in the supramarginal gyrus, previously associated with language switching (Price et al, 1999) and in the hippocampal formation and precuneus, areas involved in memory processes associated to bilingual materials (Halsband, 2006).
By contrast, and according to the hypothesis that lexical processing occurs before language membership processing, LXD did not produced any stronger activation than LGD.
Our results therefore showed a brain network that supports the BIAs model. Further studies are needed to elucidate the exact role of these areas in processing language membership information.

Figure 1. - Group fMRI map showing the activation where the LGD is stronger than the LXD under a $p<0.001$, corrected at cluster level $p<0.05$, $k = 24$.



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Imaging Techniques and Contrast Mechanism

Functional MRI

Language

Language Acquisition

Modeling and Analysis

Bold fMRI