Multivariate analysis of EEG-correlated fMRI

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Introduction:

It is now possible to acquire electroencephalographic (EEG) data during functional magnetic resonance imaging (fMRI) experiments and several groups are using this new technology to study EEG specific phenomena. A particular application of interest is the study of brain function correlated with spontaneous EEG activity in epileptic patients. A recent review of such studies, however, emphasized the need to address specific data analytic issues to improve the validity and efficiency of EEG-correlated fMRI [1]. Standard fMRI analysis, for example, involves the use of a hypothesized model to characterize signal changes expected in each voxel in the subject's brain. The validity of such models must be carefully investigated, particularly for studies of spontaneous EEG activity, where the neuronal-vascular coupling is less well understood than in standard fMRI studies of normal brain function. Furthermore, the individual examination of each voxel (i.e. a massively univariate model) may be suboptimal compared to a method that examines all voxels simultaneously (i.e., a multivariate model). Multivariate analyses are inherently more sensitive to spatial correlations between brain regions and we propose that this approach may be useful when analyzing signal changes associated with interictal brain activity in fMRI experiments. In this study we analyzed EEG-correlated fMRI data and compared the results obtained when using (A) a standard univariate analysis model and (B) a semi-flexible multivariate analysis model.

Method:

Two neurologists inspected the EEG data from four patients with idiopathic generalized epilepsy (IGE). Interictal spikes and artifacts were identified. fMRI data were preprocessed (realigned, slice-timing corrected, normalized and smoothed with a 4mm FWHM 3D filter) using SPM99 (http://www.fil.ion.ucl.ac.uk/spm/) and further analyzed with both (A) an SPM99 event-related analysis with a canonical haemodynamic response function and (B) a flexible multivariate, event-related analysis. For both analyses, events were defined by the interictal spikes in the EEG data.

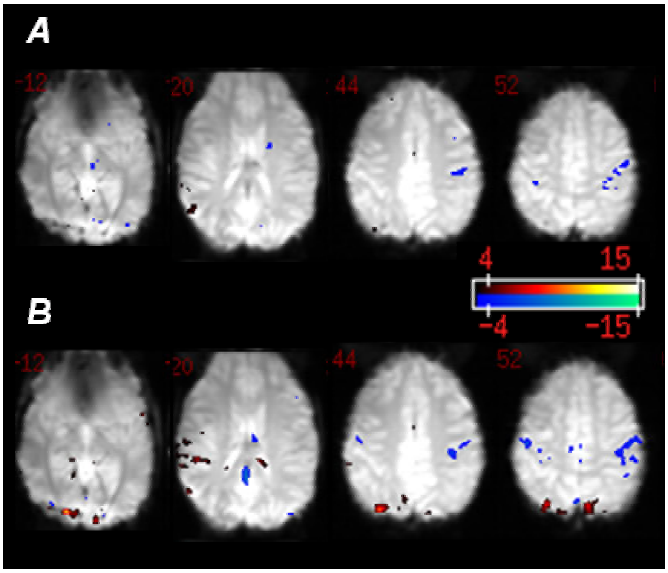

Figure 1. Results obtained for the analysis of interictal spiking activity for one subject using a (A) standard SPM99 analysis with the canonical haemodynamic response function and (B) a flexible multivariate analysis. Hot (cold) colors represent positive (negative) signal changes. Axial slices are shown in neurological format (left=left).

The NPAIRS (Non-parametric Analysis Inference Resampling Scheme) analysis software was used to generate reproducible statistical parametric maps (rSPMs) for the multivariate analysis model used (a two-class canonical variates analysis) [2].

Results and Discussion:

The two different methods we used to analyze our EEG-correlated fMRI data resulted in similar activation patterns, although additional activations were observed in the multivariate analysis (Fig. 1B) that were not seen in the univariate analysis (Fig. 1A). This appeared to be largely due to increased sensitivity. For both analysis methods, signal changes were found in the precentral sulcus bilaterally, in concordance with earlier findings in our group [3]. Further signal changes that were observed only in the multivariate results included the posterior cingulate, subcortical regions (thalamus) and the visual cortex.

These results suggest that standard analysis methods may not provide complete characterization of signal changes associated with EEG-correlated fMRI analysis. Standard analysis methods may be particularly problematic for EEG-correlated fMRI studies of interictal spiking activity in epileptic patients. The multivariate model we have used seems to be a promising alternative, perhaps due to increased sensitivity to spatial correlations between brain regions and/or increased flexibility of the statistical model.

[1] Salek-Haddadi, A. *et al.* 2003. Brain Res. Rev. 43(1):110-33.
[2] Strother. S. C. *et al.*, 2002. Neuroimage 15(4):747-71. (see also http://neurovia.umn.edu/incweb/npairs_info.html)
[3] Archer, J. S. *et al.*, Neuroimage (in press)