Analysis of simultaneous EEG/fMRI data in epileptic patients using ICA and GLM based methods.

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Introduction. A simultaneous recording of electroencephalogram (EEG) and functional magnetic resonance imaging (fMRI) is a powerful and promising tool in epilepsy [1,2]. Regions of brain activation and deactivation have been revealed by EEG/fMRI in relation to interictal and ictal epileptic discharge. The analysis of EEG-fMRI data is usually performed using the general linear model (GLM) approach with regressor created by convolution of the EEG events with a standard hemodynamic response function. This approach has many limitations when EEG epileptic events are not evident in EEG, particularly for activity originating deep in the brain. In this case a data-driven analysis like ICA (Independent Components Analysis) can be successfully applied to fMRI data although could not be obvious give a meaning to each component. In this work, we compared a data driven analysis based on ICA and a GLM approach (EEG-based) applied on simultaneously acquired EEG/fMRI data [1,3], acquired on patients affected by ictal electro-clinical activity.

Methods. Seven patients with epilepsy participated and gave informed consent, divided into a partial seizure (n=4) and generalized (n=3) group. FMRI was performed on a clinical 1.5 T magnet (Philips Gyroscan Intera). Subjects underwent two GE-EPI scans, each made up of 200 temporal dynamics, with each dynamic consisting of 20 axial slices (5 mm thickness; matrix 64x64, FOV 24x24 cm^2; TR3000 ms; TE 50 ms). EEG recording was performed using a 19-channels MR-compatible device (Micromed, Italy) and cleaned of MRI gradient and ballistocardiographic artefacts [4,5]. The fMRI data were analyzed using two methods: **(1)** data driven and **(2)** model based. **(1)** was carried out using ICA and none information extracted from EEG data was used. Spatial independent component analysis was performed with Group ICA Toolbox (http://icatb.sourceforge.net/), for significant selection of resulting spatial independent components (ICs) maps, a cross-correlation analysis was performed between the relative time-course of ICs maps and a GLM regressor (computed by convolving electro-clinical events with standard HRF). In addition, ICs maps were rejected when their time-course correlated (r>=0.3) with one of the realignment parameters, or in presence of noise at high spatial and temporal frequency. **(2)** was performed by GLM as implemented in SPM5 (www.fil.ion.ucl.ac.uk/spm). Firstly the fMRI data were pre-processed: slice-timing and motion corrected, then smoothed by convolution with 8-mm isotropic Gaussian kernel. Therefore the fMRI analysis was carried out using a regressor obtained by convolving the SPM-HRF with EEG ictal events, and modelling the motion parameters as nuisance variables.

Results. Both ICA and GLM analysis detected activation areas located in agreement with presumed electroclinical hypothesis. No deactivation was found in data coming from subjects with partial seizures, whereas in the patients with absences both activation (thalamus) and deactivation were documented. In the latter, deactivation areas were found in the so-called Default Mode Network (DMN), precuneous and fronto-occipital areas [6].

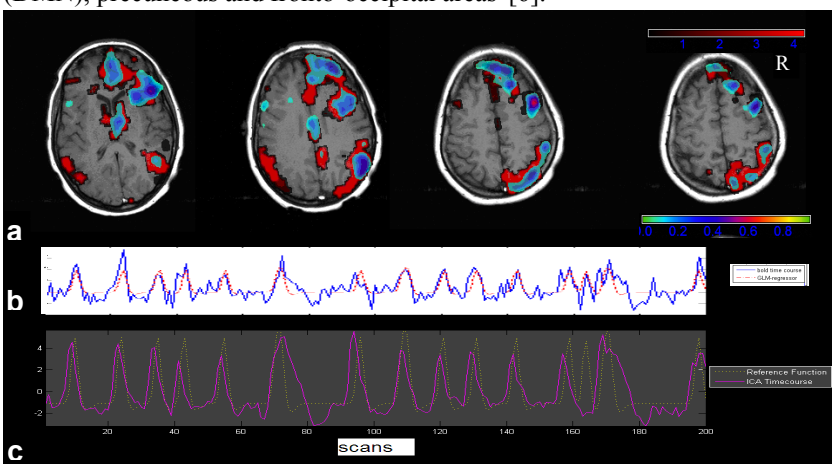

Fig. 1. (a) ICA (blue) and GLM (red) maps of fMRI changes for patient with cryptogenic partial epilepsy (CPE) and seizures arising from temporal lobe. The thresholds are Z >1.0 for IC maps and p< 0.05 (FWE corrected) for SPM, overlaid on T1 image. **(b)** Time course of BOLD signal (blue) and corresponding GLM regressor EEG related (red) . **(c)** Correlation of time course of ICs (violet) with corresponding EEG event-related GLM regressor (yellow)

Conclusion. The same BOLD patterns of activation or activation-deactivation pair in response to synchronized ictal activity were found by both ICA and GLM analysis. However additional investigation is needed to examine other ICs that could be related to epileptic activity but that are not reflected on scalp EEG. The selection of these interesting components remains the main problem of the application of ICA to EEG/fMRI data [7].

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