Minimalist EEG-recording for improving fMRI: Simple encoding of noise variables in MRI data

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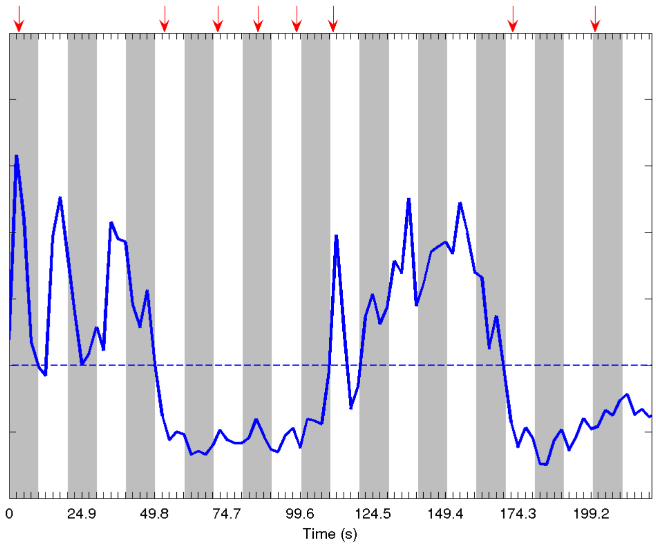
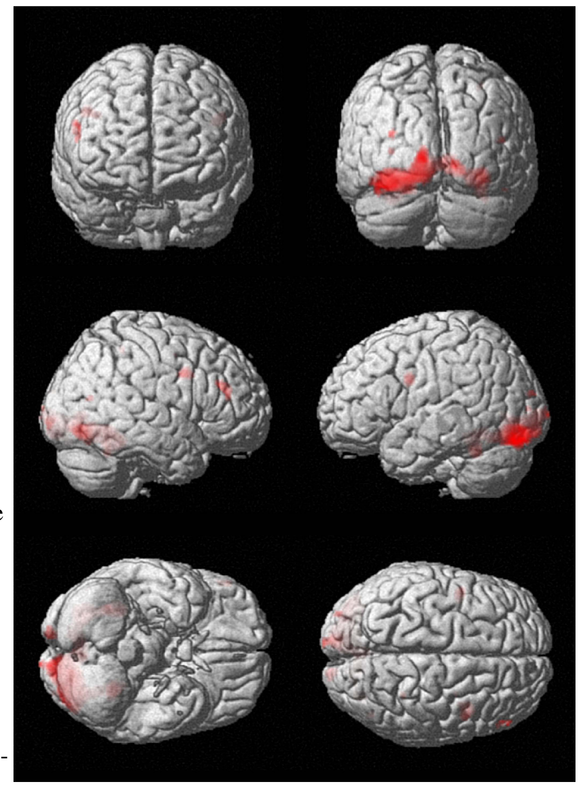
Introduction: Most fMRI experiments would benefit from simultaneous encephalographic recordings (EEG). Even for the bulk of experiments where EEG is not of primary interest, EEG helps analysis since it is typically important that studied aspects of the mental state change during experiments as planned by the experimenter [1]. It is equally important that physiological noise from head motion, pulse, eye-blinks, breathing etc. can be distinguished from signal changes induced by mental processes [2]. Hence monitoring of subject vigilance and of physiological noise should preferably be part of most fMRI experiments. Electrophysiological recordings can provide most of this information, but is typically considered too demanding in terms of hardware-needs, preparation time and analysis. We demonstrate that a minimalist approach to EEG-fMRI can improve fMRI significantly. With simple hardware and limited software adaption it can be added to most fMRI protocols.



Methods: It has been demonstrated earlier by use of a modulator that MR scanners can record electrophysiological signals including EEG while scanning [3, 4]. A lunchbox-sized battery driven 8-channel modulator was here used to modulate electrophysiological signals measured with self-adhesive carbon electrode pairs (Ambu, DK) placed above and below an eye, across the sternum, behind subject ears and high on the forehead. These positions were chosen for simplicity (no gel needed, easy mounting in less than three minutes) and since they provide direct measures of EEG alpha-activity, pulse and eye-blinks while a respiration signal can additionally be derived.

A traditional 3.7 minute fMRI paradigm involved 10 second blocks of 8 Hz flashing checkerboard interleaved with 10 second pauses. The subject was instructed to switch between alertness and a relaxed state with eyes closed approximately every minute to simulate the effect of a partially unattentive subject. The product echo planar imaging sequence of a Siemens 3T Magnetom Trio was used with the image reconstruction modified as to generate an extra set of images containing the oversampled data that are normally discarded but which here contain encoded electrophysiological data. The sequence was run with parameters TE/TR=30/2490 ms, 27 slices, 3mm isotropic resolution, matrix 128x96. The EEGs were processed as described in [4]. To demonstrate the importance of monitoring physiological noise and changes in vigilance, activation maps were calculated using SPM5 [5] with and without compensation for these variations that would often go undetected in fMRI experiments.



Results: The alpha-power derived from measured potential differences between frontal and occipital regions has clear modulation reflecting subject alertness as shown in the figure. The alpha-power was thresholded at the dashed horizontal line and the result was used to discard scans by adding columns to the design matrix. The images were realigned, spatially normalised and smoothed with an 8mm gaussian kernel prior to stastistical testing. The traditional analysis without use of EEG was ruined by the subjects lacking attention, where no voxels survived the FDR(false discovery rate) < 0.05 threshold. The expected activation in the visual cortex was recovered by including the information derived from the EEG, and the resulting activation map (FDR < 0.05) is shown in the bottom figure. However, the measured eye-blinks indicated by arrows above the graph show that the activation can not be interpreted as a result of visual stimulation alone, since stimulus locked motion occur.

Discussion/conclusion: EEG and electrophysiological signals can be measured during fMRI with limited equipment and effort. The correlation of EEG and fMRI data is greatly facilitated by having the MR and electrophysiological data stored and time-stamped together in the scanner. Compensation for the state of vigilance and physiological noise significantly increases sensitivity and aids interpretation of fMRI data.

Figure: The changes in alpha power (Top – blue line) happening approximately every minute reflect changes in attention, shown with the flashing checkerboard paradigm (Top - Gray/white pattern) and eye blinks (Top - red arrows). Activation maps (Bottom - FDR < 0.05) are improved significantly by including the effect of noise and changing vigilance in the analysis.

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