Simultaneous 64 Channel Visual Evoked Potentials and 3T fMRI Recordings

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I. Introduction.

Electroencephalography (EEG) and functional MRI (fMRI) provide joint information about the timing and location of brain activations. Simultaneous fMRI and EEG measurements will allow several classes of cognitive and clinical studies where the subject’s state is not reproducible over independent trials. Applications include detection of fMRI activity specifically linked to: 1) EEG α-waves, 2) sleep state, 3) seizure activity and 4) depth of anesthesia and/or the effects of pharmacological agents. Previous studies have demonstrated the ability to obtain spontaneous EEG data within static 1.5 Tesla magnetic field and during functional MRI [1]. However, the detection of evoked potentials (EPs) has proven more difficult due to the small amplitude of the signal (~1-10 µV) relative to the added noise (~20-200 µV at 3 Tesla) inside the magnet [2]. A previous study [3] showed that spatial filtering can be used to improve signal to noise ratio (SNR) of simultaneous EEG/fMRI recordings.

II. Materials and Methods.

MRI acquisition: The study was conducted using 3.0 T magnet (General Electric) and the standard head coil. High resolution T1-weighted IR images were acquired in each of the functional slice planes, functional MRI data were acquired from 8 axial slices (7 mm thick, gap = 2 mm, 3 mm x 3 mm in-plane resolution) sampling the entire brain using specifically designed EPI gradient echo sequence [3] with TE = 40 ms, TR = 2 s.

EEG acquisition: Continuous EEG was recorded with 64 channels using Neuroscan Amplifiers controlled by a PC (400 MHz Pentium PII). The EEG bandpass was from 0.01 Hz to 50 Hz. EOGs were recorded to monitor eye position and to register eye-movement and blink artifacts. EEG electric signals were transformed to optical signals using a custom designed (JR Ives) 64-channel transducer-preamplifier.

Visual stimuli: The stimulus, black and white checkerboard with 4 reversals per second, is generated using a SCI O2 computer, which also controls the GE scanner and the EEG recording trigger. The sequence has been designed [3] to introduce a window of 2s for simultaneous EEG/VEPs measurement, and the 8 slices were acquired in 1s and 4 VEP epochs were collected in the remaining 1s. Head motion was minimized during the functional scans by the use of an adjustable bite-bar.

Figure 1: The 64-Channel EEG cap built in our laboratory for simultaneous EEG/fMRI recordings using custom made plastic conductive electrodes to reduce both EEG noise (due to Faraday's law) and MR image artifacts (due to Eddy currents).

Figure 2: EEG Spectrogram of Oz inside and outside of a 3 Tesla magnet. (Left) inside the magnet after spatial filtering and (right) outside. The first 3.5 seconds subject’s eyes were opened and during the last 3.5 seconds the subject’s eyes were closed generating the 10 Hz of alpha activity.

III. Results.

The 64 channel cap built in our laboratory (Figure 1) using plastic conductive electrodes enables us to collect EEG data with lower noise (estimated $P_e \approx 1.122 \pm 8 \mu V$, $Vpp = 664 \mu V$) compared with a 64 channel metal electrodes cap (estimated $P_e \approx 2.260 \pm 8 \mu V$, $Vpp = 743 \mu V$). A spatial filtering of data was used to improve SNR of EEG recordings, which enables us to observe α-waves in the standard eyes open/closed paradigm (Figure 2). For the first time 64-channels were used in simultaneous EEG/fMRI (fMRI activations, not shown, were located in visual areas) recordings, which allowed us to recover VEP waveforms (Figure 3).

In conclusion, by increasing the number of EEG channels we have achieved an improvement of spatial filtering, which is a crucial step in the process of EEG noise removal in simultaneous EEG/fMRI recordings.

Figure 3: Visual Evoked Potential (VEP) collected (left) outside and (right) inside a 3 Tesla magnetic field during a fMRI study after spatial filtering. 850 selected epochs were used in the averaging and both VEPs were collected at 5 cm above the inion-midline. The spatial filtering is capable of recovering most of the shape and amplitude of the P2 and N3 peaks.

References.