

Simultaneous Acquisition of EEG and fMRI Employing Novel Noise Cancelling Technology

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Recent advances in the development of neuroimaging techniques capable of combining, in real-time, electroencephalographic (EEG) and functional MRI (fMRI) data, enable the localization of areas of increased blood flow associated with specific EEG events, and will find applications in both clinical neurological and basic neuroscience areas (Zijlmans et al., 2007; Ritter P. & Villringer A., 2006)). The traditional approach to removing the two main sources of induced noise: a) scanner induced e.g. radio frequency (RF) and switching gradient magnetic fields, and b) ballistocardiogram effects, have relied upon two strategies, with a) relying on software post-processing approaches and b) various matched template subtraction algorithms. The main problem with a) is that the removal of gradient artifact is totally dependent on a precise prediction of the timing of the induced noise and its characteristics. This has required collecting the EEG and all induced noise using large dynamic-range amplifiers, high sampling rates and precision synchronization of the MR scanner and EEG clocks. The raw data thus collected has a very low signal-to-noise ratio (SNR) and must be post-processed to recover usable EEG. Consequently the investment of time and technical expertise has been significantly greater than the quantity of acceptable EEG data recovered.

In order to eliminate synchronizing of MR and EEG clocks and reduce software processing of data, the SNR of EEG acquired during MR scanning must be improved significantly. Since large scanner artifact enters EEG by means of time-varying magnetic fields inducing voltages on the loops formed by electrodes and lead wires, innovative **analogue noise cancellation** techniques may be used to improve SNR prior to digitization. A natural progression from the classic EEG ear reference is to provide a matched reference for each scalp electrode, with a twisted wire pair connecting electrode and reference to a differential amplifier. If the reference signal is a matched version of the noise component appearing in the scalp channel, substantial reduction of noise may be effected by analog subtraction alone. The electrodes for the reference should not contact the scalp, but instead it should contact a reference layer that closely fits the contours of the head while remaining electrically insulated from the body.

We have devised a flexible electrode cap with such a reference layer, one that closely approximates the electrical characteristics of the human scalp. The fMRI scanner artifact induced on each of the paired scalp and reference loops and electrodes

are thereby closely matched. Improving the SNR is accomplished by adaptive subtraction of the reference from the scalp signal in the EEG amplifier. Using this approach, we have been able to improve SNR by a factor of 10,000:1 or more, and we are able to capture clean EEG without the use of post-processing or clock synchronization. Residual ballistocardiogram and scanner induced artifact appearing in the amplifier output are removed as data is collected, utilizing bespoke software algorithms operating in real time. EEG data is thereby displayed during scanning.

We have developed a fully integrated 21-channel EEG system, for use during fMRI scanning, known as fEEG™ (Kappametrics, Inc., 2008). EEG data recorded during a typical fMRI scan is shown in Figure 1. The EEG data on the left was recorded with the analogue noise cancellation disabled, and the EEG data on the right was recorded with the analogue noise cancellation enabled.

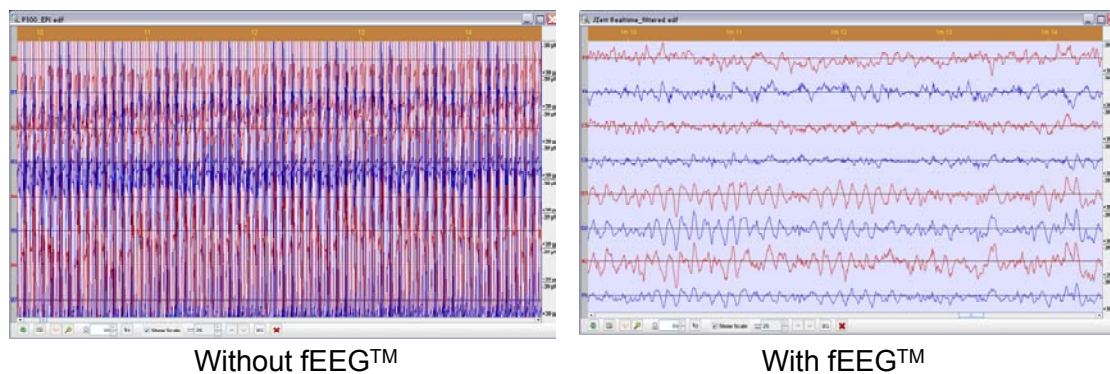


Figure 1

The system is currently available for investigational use. Pending successful testing, we envisage fEEG to enter the basic science and clinical research arenas in early 2009, with subsequent entry into the clinical diagnostic arena later pending regulatory approval.

References:

Kappametrics Inc. (2008), 14150 Newbrook Drive, Suite 105, Chantilly, VA 20151, <http://www.kappametrics.com>

Ritter P. & Villringer A. (2006) Simultaneous EEG-fMRI. [Neuroscience & Biobehavioral Reviews](#), **30(6)**: 823-838

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