EEG / EOG - fMRI Cold head artifact removal

E. Featherstone[1], O. Josephs[1], R. Deichmann[1]

[1]Wellcome Department of Imaging Neuroscience, London, United Kingdom

Introduction

In fMRI studies, it is often desirable to record EEG or EOG data during the scanning process. However, the scanner's cold-head refrigerant pump often causes problematic interference. EOG eye blink signals are sufficiently large that they can be seen clearly despite the interference. However eye movement EOG signals and EEG signals are typically several times smaller and are obscured by noise. The interference from the cold-head is very repetitive lending itself to being modelled and subtracted from EEG and EOG time series. Several techniques have been described such as active noise cancellation (1-2) or subtraction of mean noise (1,5). In this work we describe a new method based on dividing the EOG data into blocks of a suitable length and applying high pass filtering. This method works even if there is a slow drift in timing of the pump.
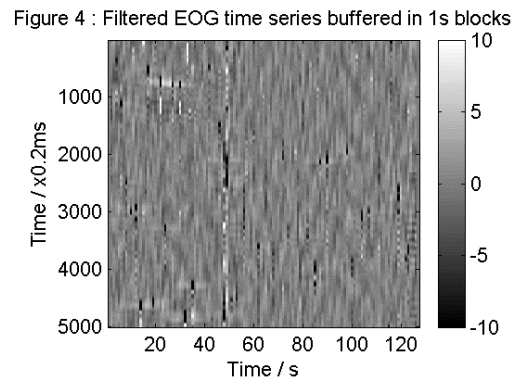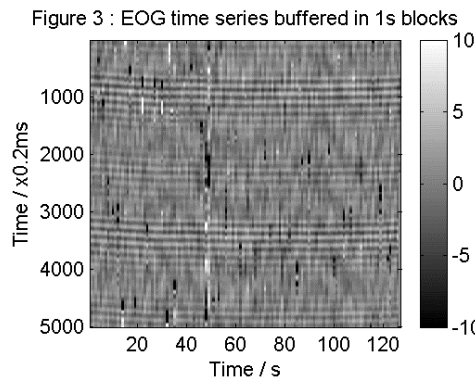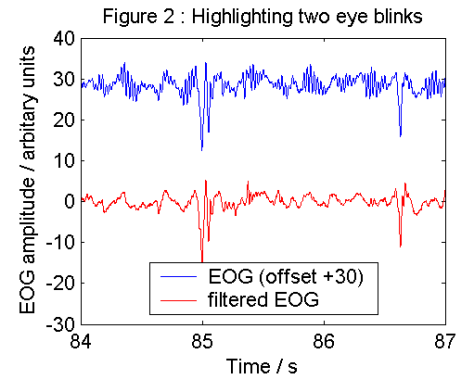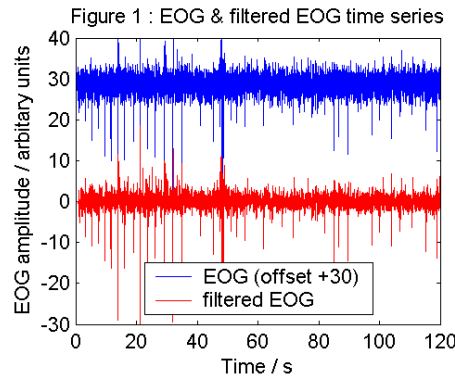
Method

Apparatus : EOG signals were recorded from a pair of electrodes and reference electrodes attached to a subject lying inside a Siemens Allegra 3T head only MRI scanner. The scanner was not operating. The EOG leads were connected to an MRI compatible EEG amplifier system (1) linked to a CED 1401 (3) and PC running Spike (3) data acquisition software. A sampling rate of 5000 samples per second was used for the EOG recording to allow the interfering signals to be properly characterised. One recording run of approximately two minutes each was made whilst the subject blinked normally.

Processing : The data was exported from Spike and imported into Matlab (4) for processing. The data time series was divided into blocks equal in length to twice the period of the cold-head pump, 5012 samples, and reformed into a matrix with the blocks vertical. The array was high pass filtered in the horizontal direction. The filter parameters were chosen by trial to best remove the interference. The data was then reformed into a time series.

Results and Discussion

Figure 1 (top trace) shows a typical EOG recording. Eye-blinks are clearly identified as large negative spikes in a background of interference and eye movement EOG signals. Closer inspection (figure 2, top trace) shows that the artefact from the pump consists of short duration pulses with a frequency of approximately 30Hz, occurring every 500ms. Figure 3 shows the EOG data as greyscale intensity after being divided into blocks of a length equal to two periods of the cold-head pump. The pump artefact is now evident as horizontal stripes, two cycles of the pump can be seen clearly. Eye-blinks show as black points. The artefact drifts slightly in time, up to approximately 15ms. Filtering removes almost all trace of the pump artefact (figure 4). The eye blinks are still clearly visible. Reforming the data into a time series (figure 1, bottom trace) shows eye blinks as before against a smaller background of noise. Close inspection (figure 2, bottom trace) shows that the pump artefact has been successfully removed with little effect on either the low level EOG signals or the larger eye-blink signals.

Figure 1 : EOG & filtered EOG time series

Figure 2 : Highlighting two eye blinks

Figure 3 : EOG time series buffered in 1s blocks

Figure 4 : Filtered EOG time series buffered in 1s blocks

Conclusion

The described method allows the reduction of interference artefacts caused by the cold head pump from the EOG signals, revealing clearly the eye movement signals. This method works even where there is a very slow drift of the cold head pump timing. Transient effects in the interference can also be handled using a more complex model.

References

1. Allen, PJ et al. Neuroimage. 2000 Aug; 12(2):230-9
2. Featherstone, E et al. Proc. Intl. Soc. Mag. Reson. Med. 9 (2001):1226
3. Cambridge Electronic Devices, www.ced.co.uk
4. Mathworks Inc, www.mathworks.com
5. Josephs, O & Turner, R. Neuroimage. 1998; (7):s590