Initial experience of combined EEG fMRI development work at 3T.

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INTRODUCTION

SINAPSE support has provided equipment used to simultaneously record EEG and fMRI data from studies involving human volunteers on our Siemens 3T Trio MRI scanner at the Clinical Research Centre, based at Ninewells Hospital, Dundee. We report our preliminary findings from simple visual working memory and auditory tasks.

MATERIALS AND METHODS

Ten normal volunteers underwent combined EEG and fMRI investigations on the 3T scanner using a transmit body coil and a 12-channel receive-only head coil.

Figure 1. EEG preparation

A 64 channel EEG Brain Cap MR cap (EasyCap, Herrsching, Germany) was applied. Electrode impedances were below 25kΩ prior to scanning. Data was acquired using BrainAmp M+ amplifiers (Brainproducts, Munich, Germany) and Brain Vision Recorder software .

Sampling rate was 5 kHz, downsampled to 250 Hz after MR artifact correction. EEG acquisition was synchronised to the scanner clock.

Visual working memory (N-Back) and auditory attention control tasks were generated and presented using Presentation software (Ver. 12.2) and Nordic Neurolabs (NNL) (Bergen, Norway) head-coil mounted goggles and electrostatic headphones. MR-compatible button response boxes (Current Designs, PA, USA) were used to record volunteer responses to stimulus presentation. Onset of Presentation software was synched to MR volume signals. Stimulus presentation markers, volunteer responses and scanner volume triggers were all logged in the EEG recordings via a purpose-built interface. The visual working memory and auditory attention paradigm fMRI acquisitions consisted of 260 and 336 EPI volumes respectively, with whole brain coverage (30 -36 axial slices) from all volunteers using a standard fMRI T2*-weighted EPI imaging sequence; TE=30 ms, TR=2500 ms, FOV 240 mm, matrix size 64 x 64. The head was secured using foam pads.

The visual working memory task consisted of 4 x 4 blocks of trials of 0, 1, 2 & 3-back letter repetitions. Instructions and letters were presented visually. Participants indicated with the right index finger whether a letter had occurred for the first time and the middle finger if the item was a repetition. In the 0-back condition middle finger responses were to the letter 'X'. The main prediction for the ERP responses was that there would be an increase in left frontal negativity associated with increased working memory load.

The auditory attention control task required a forced choice 'odd' or 'even' number parity decision on most trials. The numbers 1-10 were used and were presented in the midline of the auditory field. On some occasions a number would be accompanied by a lateralised novel sound which was to be ignored. When the number zero or an isolated novel sound was presented participants were asked to inhibit responses to these stimuli. The right, index and middle fingers were used for odd and even numbers button responses.

The main predictions for the auditory task ERPs were as follows: 1) In all trials with a number decision, a P3B deflection will be observed, consistent with the update of working memory resources. 2) The left frontal region will be relatively more negative, consistent with the use of verbal resources to perform the parity decisions. 3) Late slow wave differences will differentiate 'go' from 'no-go' trials. 4) Simultaneous number and novel stimuli will not evoke an attention orienting response because the novel stimulus occurs at around the time that goal-directed stimuli are expected and are being processed. 5) 'Novel Only' stimuli may activate the stimulus-driven attention reorienting network if no number is available to process but this will not result in orienting because of suppression by the goal-driven elements of the attention reorienting system (Corbetta et al., 2008).

RESULTS

AUDITORY ATTENTION CONTROL TASK

Auditory event-related potentials were successfully acquired despite the significant background scanner noise. Results are summarised in Figure 2.

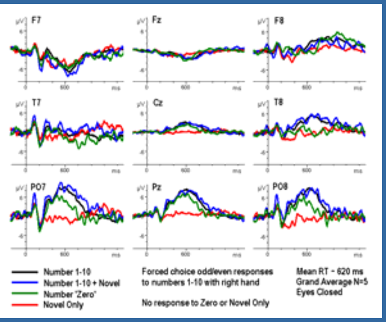

Figure 2. Auditory event-related potentials recorded during fMRI scanning.

ERP deflections at T8 dissociate 'go' from 'no-go' trials. The large positive deflections at ~ 600 ms at Pz in all number decision conditions is an auditory P3 complex. The deflections at PO7 and PO8 in the no-go 'Zero' condition allow one to differentiate the 'slow wave' associated with behavioural response from the P3b associated with the resolution of stimulus processing and updating of working memory. In the case of 'Novel Only' stimuli only a small right lateralized P3a response (~ 550 ms) is observed. This is consistent with activation of the stimulus-driven part of the attention reorienting network without activation of the goal-driven system and attention orienting (Corbetta et al., 2008).

VISUAL WORKING MEMORY TASK

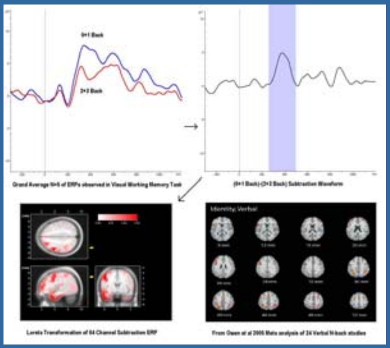

Figure 3. Visual ERP deflections distinguish **when** low working memory conditions differ from high working memory task conditions. Low Resolution Tomography Analysis (LORETA) of ERP difference wave provides evidence of **where** brain electrical response originate and these areas show overlap with some areas identified in many fMRI studies (Owen et al. 2005).

TECHNICAL ISSUES

Figure 4. shows the Fast Fourier Transform (FFT) of the EEG before and after template-based scanner artifact correction. Some artifact remains. Exact frequencies seem to vary from one recording session to the next.

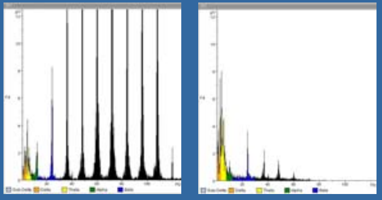

Figure 4. Effect of scanner artifact rejection on EEG frequency spectrum.

Scanner artifact reduction: care should be taken to check inter-volume timing even when EEG acquisition is synched to the scanner clock as small variations in recorded timing of volume markers do occur and will reduce effectiveness of artifact reduction.

The EEG amplifiers should not be placed in the bore of the magnet unless the head coil is a combined transmit/receive device or the amplifier shielding will become warm and the thermal cut-outs will operate. Cabling from the cap to amplifiers should be kept in the middle of the magnet bore to minimise scanner artifact.

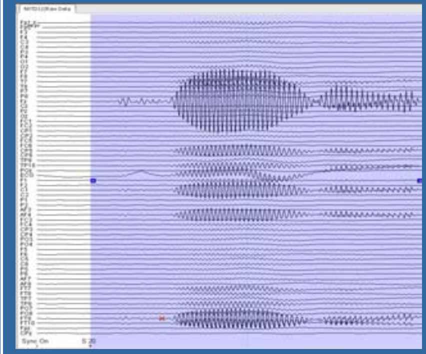

Figure 5. Audio artifact

Audio artifact: Our NNL electrostatic Headphones generate an electrical artifact with a dominant frequency of around 120 Hz in many participants. Figure 5 shows the waveforms generated on several EEG channels by presentation of the word 'zero'. The amplitude modulation appears to follow the envelope of the sound

CONCLUSIONS

Our initial experiences of combined EEG-fMRI at 3T in Dundee have, in general, been successful.

Auditory event-related potentials can be recorded in the MRI scanner despite significant background noise. These measures provide evidence of specific activation of systems involved in attention, memory and motor control. We look forward to analyzing the fMRI correlates of this study.

Visual event-related potential correlates of working memory performance provide compelling evidence of the specific sources of cortical activation as well as providing information about the timing of these events. These results are consistent with previous fMRI studies of working memory function.

Scanner artifact reduction is largely effective

Cardioballistic artifact rejection is less satisfactory

FURTHER WORK

SPM analysis of the fMRI data sets is currently underway

Alternative cardioballistic artifact reduction techniques are being explored.

ACKNOWLEDGEMENTS

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Ethical approval and informed consent was obtained from the NHS Tayside local ethics committee and volunteers respectively.
T1 and T2 diagnostic scans were also acquired for radiological reporting.