Poster Number: 1624

Detecting gamma frequency neural activity using simultaneous multiband EEG-fMRI

Makoto Uji[a], Ross Wilson[a], Susan T. Francis[b], Karen J. Mullinger[a,b]*, and Stephen D. Mayhew [a]*

s.d.mayhew@bham.ac.uk

a. Centre for Human Brain Health (CHBH), University of Birmingham, Birmingham, UK.
b. SPMIC, School of Physics and Astronomy, University of Nottingham, Nottingham, UK.

*equal leads in this work

Introduction:

Synchronization of gamma frequency (>35Hz) EEG activity is linked to cognitive and sensory behaviour as well as being widely cited as the closest neuronal correlate of the BOLD fMRI signal[1]. However, the majority of gamma-BOLD studies were conducted in the visual[2,3] or auditory[4,5] modalities, therefore a deeper understanding necessitates extension to the motor domain. Simultaneous EEG-fMRI is an ideal method to investigate gamma-BOLD correlates non-invasively in humans, however, residual gradient artefacts typically obscure gamma frequency EEG activity when acquired with fMRI. Accelerated fMRI methods such as multiband (MB)[6,7] allow whole-brain coverage in a sparse fMRI scheme which incorporates MR gradient “quiet periods” thus potentially useful to overcome EEG gradient artefacts during fMRI acquisition.

Aim**: **To assess: (1) the feasibility of simultaneous EEG-MBfMRI, both safety aspects related to the higher RF power of MB excitation and EPI image quality[8,9,10]; (2) the potential to investigate relationship between gamma activity and BOLD responses in motor cortex.

Methods

EEG data were acquired from 64 scalp channels at 5kHz (Brain Products). MB fMRI acquisition (Gyrotools) used a 3T Philips Achieva scanner.

Safety testing – agar phantom

- The EEG cap was connected to a conductive agar head-shaped phantom
- Fibre-optic thermometers (Luxtron) monitored the temperature change during 20-minute scans with MB factor = 4 and SPIR fat suppression.
- Tested upper SAR limits using:

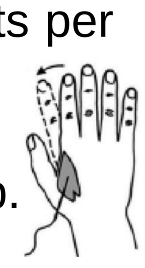
1) GE-EPI (TR/TE=1000/40ms, SENSE=2, slices=48, B1 RMS=1.09μT, SAR/head=22%)
2) PCASL-GE-EPI (TR/TE=3500/10ms, SENSE=2, slices=32, B1 RMS=1.58μT, SAR/head=46%)

Image quality – 3 healthy adults

- Tested 5 GE-EPI sequences (Table.1).
- Image quality was assessed by comparing temporal SNR (tSNR) of grey matter voxels.

EEG-fMRI motor study – 10 healthy adults (8M)

- 4 right-hand index finger abduction movements per trial with 16s interstimulus interval (Fig.1)
- All abductions performed in 1.5s period, each in response to an auditory cue, 1kHz beep.



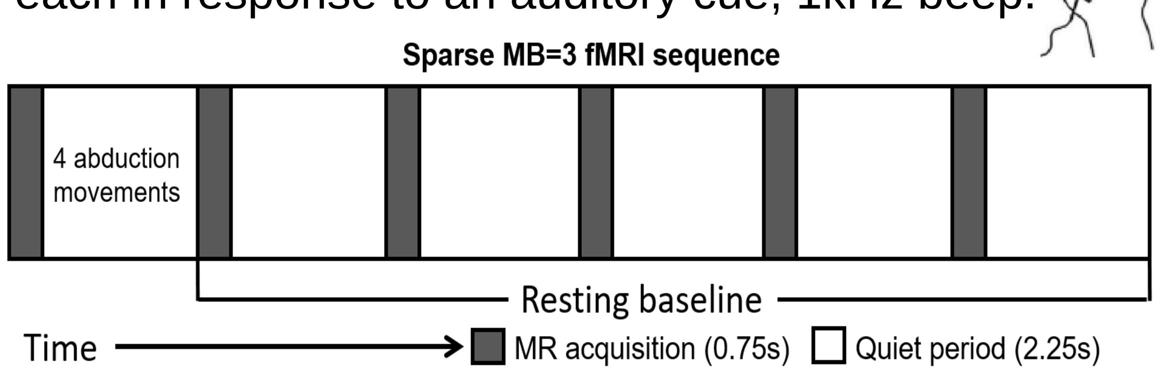


Figure 1: Experimental paradigm

- 4 runs of 30 trials, 120 trials in total per subject
- Sparse GE-EPI: MB=3, SENSE=2, TR/TE=3000/40ms, 33 slices, *FA=79°*, volumes=192, voxels=3mm^3, SAR/head < 7%
- EEG-MRI clocks synchronised
- EEG electrode positions digitised (Polhemus)

Data analysis

EEG

- Gradient and pulse artefacts were corrected, data downsampled (600Hz) and epoched -16–2s relative to auditory cue onset (BrainVision Analyzer2).
- Trials contaminated with movement artefacts were removed. Eye-blinks/movements were removed (ICA, EEGLAB) and data were average referenced.
- An LCMV beamformer[11] (noise regularization=1%) was employed with individual BEM head models (Fieldtrip[12]) to create Ŧ-stat images of changes in gamma (55–80Hz) power to finger abductions [active: 0–1.5s & passive: -9.0 to -7.5s windows].
- A broadband (1-120Hz) timecourse of neural activity was extracted from the peak T-stat location in the contralateral (left) motor cortex (cM1). Time-frequency spectrograms were calculated using multitaper wavelets[3].
- The mean gamma power per trial (0-1.5s after auditory cue onset) was mean subtracted to form a regressor for fMRI analysis.

fMRI

- Data were motion corrected, smoothed (5mm) and normalised to the MNI template (FSL).
- First-level GLM analysis employed 2 regressors: 1) boxcar abduction movement, 2) parametric modulation of single-trial gamma activity, convolved with the double-gamma HRF.
- Data were grouped over runs and subjects using second-level fixed and third-level mixed effects.

Results

Heating effects

- The greatest temperature change seen for the GE-EPI sequence was 0.6°C in the ECG electrode (**Fig 2**)
- The PCASL-GE-EPI resulted in the greatest heating effect (ECG ~0.9°C)

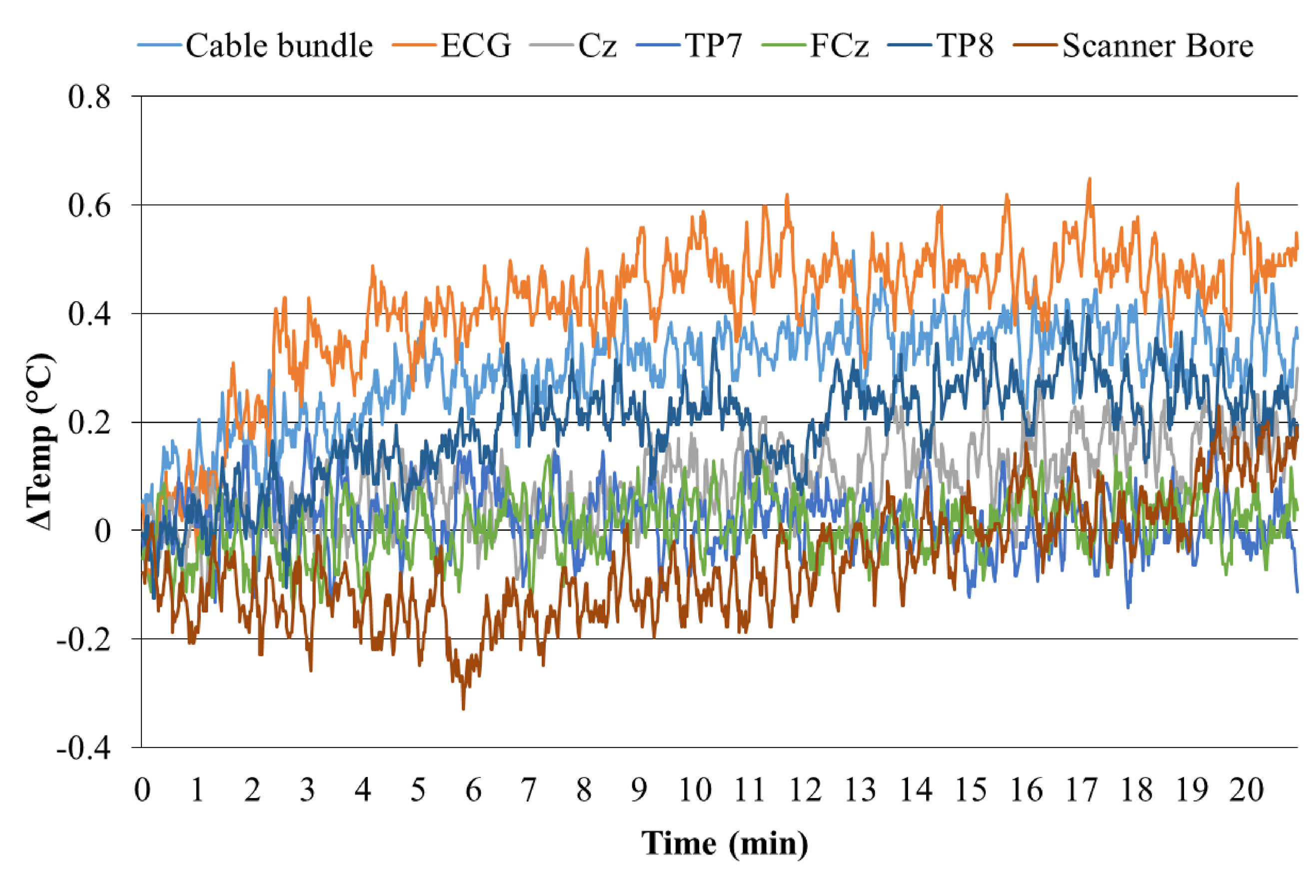


***Figure 2:** Temperature changes at EEG electrodes, cable bundle and a control location on the scanner bore during a 20-minute GE-EPI scan. Temperature changes were calculated relative to a 5-minute baseline recording made before the scan.*

Image quality

- Little variability in tSNR between sequences
- MB=3, sparse acquisition chosen for further experiments (red box)

Multiband Factor	Slice acquisition spacing	tSNR ± *SD*
1	Equidistant	74 ± 40
2	Equidistant	72 ± 39
2	Sparse	67 ± 37
3	Equidistant	68 ± 37
3	Sparse	74 ± 38

***Table 1:** Mean tSNR calculated during five MR sequences: MB: 1-3; acquisition type = equidistant or sparse. All other parameters were constant: TR/TE=3060/40ms, SENSE=2, slices=36, FA=79°, voxels=3mm^3, volumes=41*

EEG-fMRI motor study

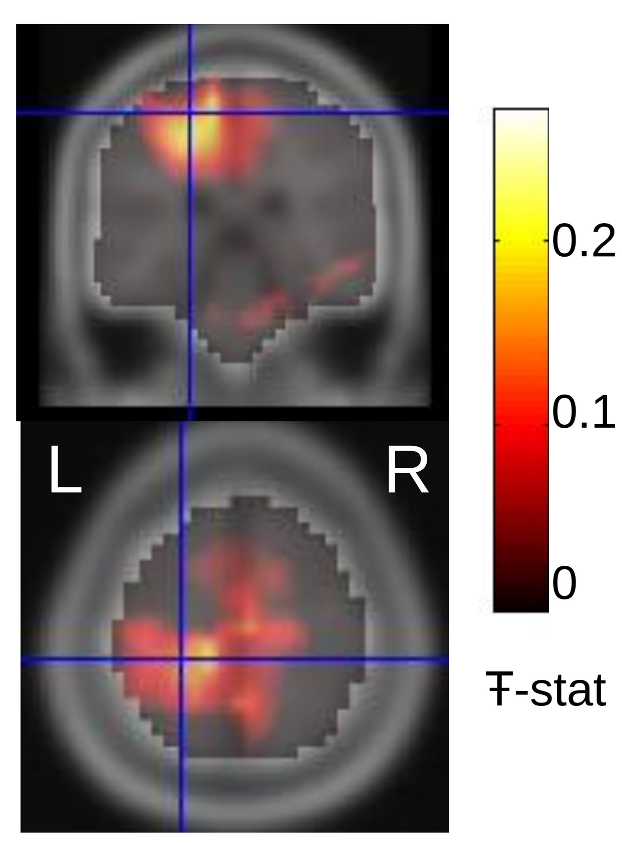


***Figure 3:** Group mean beamformer Ŧ-stat maps of increase in gamma-power during abductions compared to baseline. Cross hair show mean peak location over subjects.*

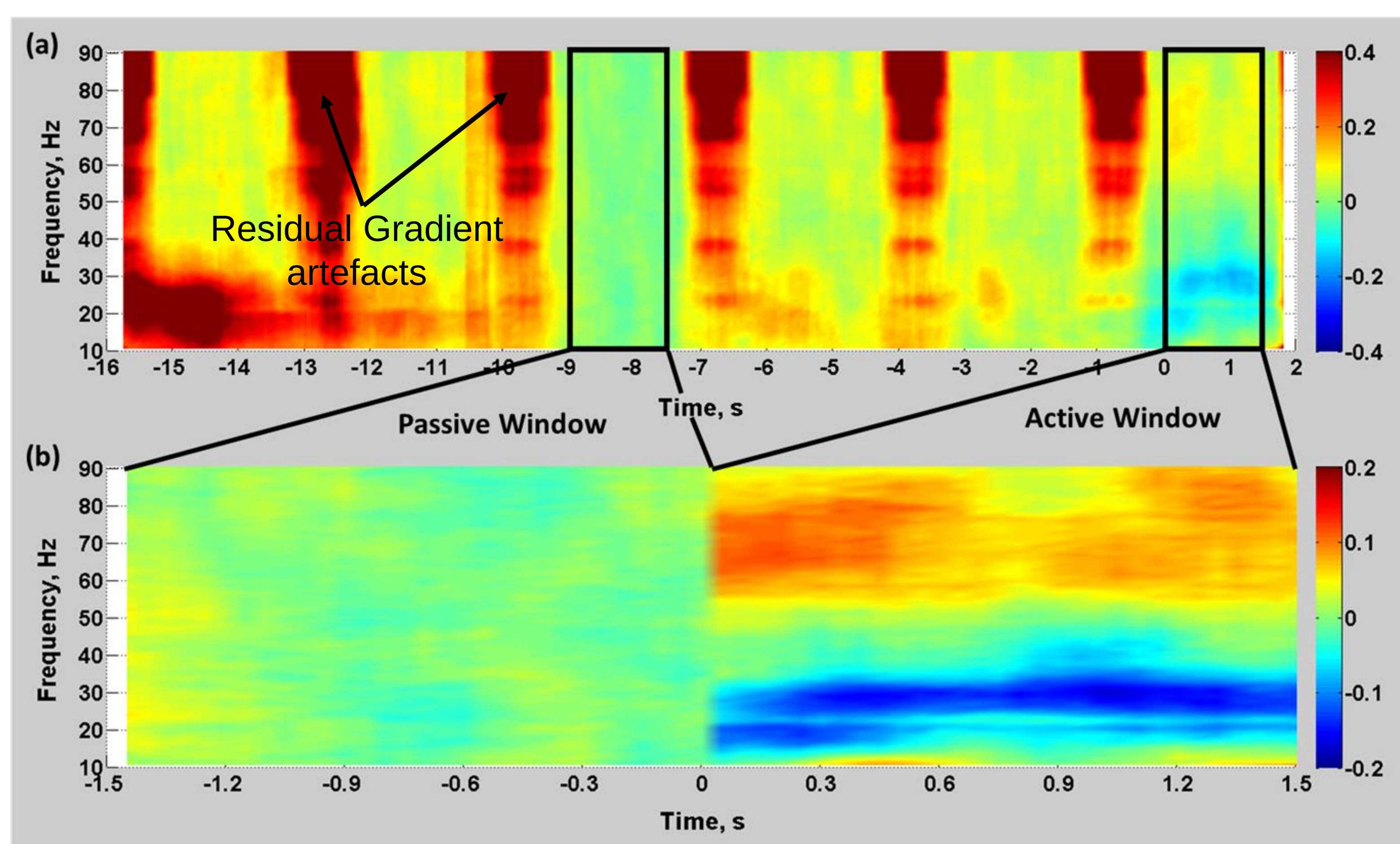


***Figure 4:** Group mean time-frequency spectrograms of cM1 EEG responses: a) 18s whole-trial duration: shows residual gradient artefacts during EPI acquisition; b) Gamma power increases and beta (15-30Hz) power decreases are seen during the active window (0-1.5s) compared with passive window (-9 to -7.5s).*

- Increase in cM1 (left) gamma power during right-hand finger abductions (**Fig 3&4**).
- Main effect BOLD activation to the abductions and positive gamma-BOLD correlation in cM1 (**Fig 5**).
- Correlation was focal to the central sulcus and motor hand-knob, supporting a tight coupling between BOLD fMRI and gamma EEG responses[3,13].

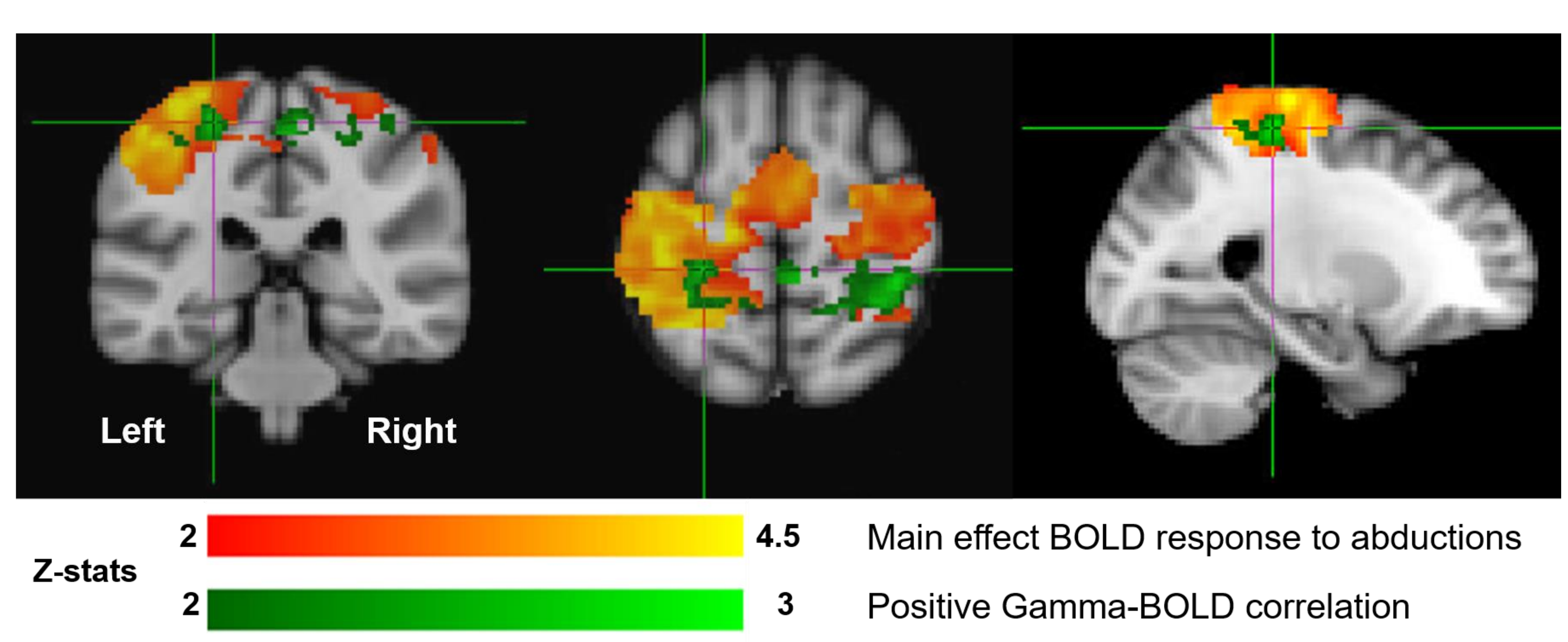


***Figure 5:** Group average fMRI mixed effects results. Main effects and single-trial gamma correlations are cluster corrected with p<0.05, masked to motor cortex.*

Summary

Safety: MB EEG-fMRI acquisition was safe for GE-EPI with MB factor = 4
However, in future work safety testing of the specific MB sequence implementation is still needed.

Data quality: MB-fMRI provided “quite periods” which allowed reliable measurement of EEG gamma and beta responses. The addition of the EEG to MB-fMRI did not significantly degrade MR image quality.

Neurovascular coupling: Our results support a tight, positive coupling between BOLD fMRI and gamma EEG responses in motor cortex, similar to previous reports in visual cortex[14]

Our work shows the potential of combining EEG-MB fMRI for advanced study of human brain function

[**1**] Fries Annual Review of Neuroscience 32:2009. [**2**] Logothetis Nature 453:2008. [**3**] Scheeringa et al. Neuron 69:2011. [**4**] Mukamel et al. Science 309:2005. [**5**] Mulert et al. Neuroimage 49:2010. [**6**] Feinberg et al. PLoS One 5:2010 [**7**] Moeller et al. Magn Reson Med 63:2010 [**8**] Auerbach et al. Magn Reson Med 69:2013 [**9**] Mullinger et al. Int J Psychophysiol 67:2008 [**10**] Chen et al. Neuroimage 104:2015 [**11**] Van Veen et al. IEEE Transactions on Biomedical Engineering 44:1997 [**12**] Oostenveld et al. Comput Intell Neurosci 2011:2011 [**13**] Logothetis J Neurosci 23:2003 [**14**] Logothetis et al. Nature 412:2001