Failure to Detect Magnetic Source Dephasing Corresponding to ERP Generation

L. Tang[1], J. C. Gatenby[1], M. J. Avison[1], J. C. Gore[1]
[1]Vanderbilt University Institute of Imaging Science, Nashville, TN, United States

Introduction:

FMRI based on the BOLD effect is widely used for mapping brain activity in humans, and relies on the detection of changes in regional blood flow and oxygenation associated with local changes in neuronal activity. While imaging based on BOLD contrast has good spatial resolution and sensitivity, the hemodynamic change that gives rise to BOLD signals is slow and is only indirectly related to neuronal activity. Several reports have suggested that neural activity may be mapped by MRI with greater temporal resolution by detecting the local magnetic field perturbations associated with neural electric currents. This general approach has been termed magnetic source MRI (msMRI). In the present study, we adapted the method of Xiong et al. [Xiong, 2003] to investigate whether we could detect an msMRI signal correlated in time and amplitude with two well defined event related potentials (ERPs), and in locations previously identified as putative generators of the ERPs by the correlation of their BOLD signal amplitudes with ERP amplitudes. Two ERPs were investigated; one, the auditory oddball P300, whose amplitude increases with decreasing frequency of the oddball event [Horovitz, 2002], and two, the face-sensitive N170, whose amplitude decreases with increasing noise level in the face presentation [Horovitz, 2004]. We have so far been unable to identify reliable msMRI signal amplitude changes that correlate with the corresponding ERP or BOLD data.

Method:

Auditory oddball - Auditory stimuli generated by E-prime (Psychology Software Tools, Inc) were presented to healthy subjects every 1.2s. The frequent stimuli were 1kHz tones of 100ms duration, while rare stimuli -"oddballs"- were 1.5kHz tones of the same 100ms duration. The interval between oddballs was varied within runs to produce oddball presentation frequencies of 4%, 6% and 8%. In total 50 oddballs for each frequency group were presented in 5 runs. ERPs were collected from electrode Fz using an electrocap and recorded on a computer running Scan4.2 and controlling SynAmp amplifiers (Neuroscan, Inc). Functional images were acquired on a 3T Philips Achieva scanner using a gradient echo EPI sequence (TR/TE=1.2s/35ms, flip angle=70^{o}, FOV=22x22cm^{2} and acquisition matrix size=80x80 reconstructed to 128x128), then analyzed using SPM2 and a custom analysis software running under MATLAB. MR images were acquired with 325ms/425ms/525ms delays relative to stimulation onset. These delays were chosen in order to be able to study the time course of the T2*-weighted MR signal before and after the mean time of the maximum P300 amplitude.

Face processing - Visual stimuli were presented to healthy subjects for a period of 500 ms every 1.5s. The frequent stimuli were pictures of cars, while pictures of faces with different noise levels were presented every 19.5s. Functional images were acquired using gradient echo EPI (TR/TE=1500/35 ms), then analyzed using BrainVoyager. MR images of slices including the fusiform gyri were acquired with 170ms/180ms/400ms delay relative to stimulation onset in different runs. These delays were chosen in order to be able to study the time course of the T2*-weighted MR signal before and after the mean time of the maximum N170 ERP amplitude.

Results:

We confirmed the inverse relationship between P300 amplitude and "oddball" frequency, and the monotonic decrease of the N170 amplitude as Gaussian noise is added to the picture of a face. Conventional event-related BOLD-fMRI analyses identified the same regions that showed covariations of BOLD signals and ERP amplitudes as previously described [Horovitz, 2003; 2004]. For example the BOLD signals in the supramarginal gyrus and anterior cingulate and the P300 amplitude at Fz showed significant inverse correlations with the "oddball" frequency, and the BOLD signals in fusiform gyrus [Horovitz, 2003] and the N170 amplitude showed inverse correlations with noise level [Horovitz, 2004].

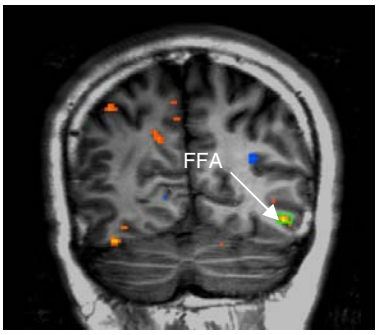

Fig.1 BOLD activation map

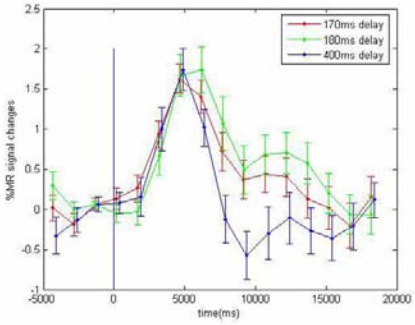

Fig.1 b Signal time courses of FFA

Despite these robust BOLD activations, we were unable to detect any significant change in the T2*-weighted signal in these locations that correlated temporally with the timings of the ERPs: Fig1a shows the activation of facial fusiform area (FFA) associated with the N170, while Fig 1b compares the T2*-weighted signal time courses for runs where images were synchronized to 170, 180 or 400 ms post stimulus, and shows no difference in the mean signal at any of those times, and no difference from the prestimulus signal. Similarly, no significant signal changes were seen at times corresponding to the N300 ERP in the auditory oddball condition.

Discussion:

These results used an event-related design to probe the response of the T2*-weighted MRI signal at the time and in the locations of well-characterized ERP generators. We found no reliable evidence of changes in the MRI signal occurring at those times and locations when maximal neural activity (as judged by the surface ERP) is expected. These results suggest that the effects of neural dipole currents on the T2*-weighted signal which have been proposed as a direct measure of neural activity), lie below the level of detection at 3T, or that the maxima in these ERPs do not correspond to times of maximal current-induced dephasing.

Acknowledgments:

We thank Silvina Horovitz , Chris Cannistraci and Robin Greene-Avison for assistance in the design of experiments and technical support.

References

1. Horovitz SG, et.al. MRI 2002; 20(4):319-325; **2.** Horovitz SG, et.al. NeuroImage 2004; 22:1587-1595; **3.** Xiong J, et.al HBM 2003; 20:41-49.