Amplitude correlation between stimulus-induced MEG and BOLD fMRI signals

R. Chu[1], T. Holroyd[2], J. A. de Zwart[1], P. van Gelderen[1], M. Fukunaga[1], J. H. Duyn[1]

[1]LFMI, NINDS, National Institutes of Health, Bethesda, MD, United States, [2]MEG core facility, NIMH, National Institutes of Health, Bethesda, MD, United States

Purpose:

BOLD fMRI signals are related to activity-induced changes in blood flow and appear to correlate with changes in synaptic activity as measured by transcranial electrodes [1]. In many brain areas, including the pyramidal cell layers of human visual cortex, stimulus-induced increases in synaptic activity lead to coherent electrical signals. These can be observed outside the brain with non-invasive methods such as EEG or MEG. Here we investigate how the amplitude of MEG signal correlates with that of BOLD fMRI.

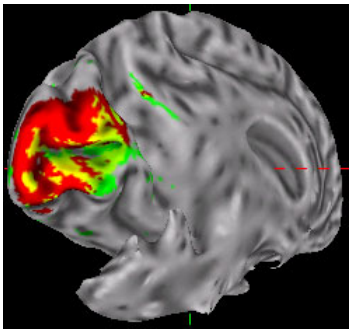

Fig. 1: Localization differences between MEG (red) and fMRI (green). Overlapping regions are in yellow.

Materials and Methods:

Five healthy subjects, free from neurological disorders and visual abnormalities, underwent both fMRI and MEG. A parametric visual task was performed using a flashing disk of uniform intensity, with the flashing frequency stepped from 2-16 Hz (step 2) and back. For each frequency, there was 4-8 s of flashing disk, followed by 4-8 s of rest (darkness). Two complete cycles (2-16-2 Hz) were executed. A field with a visual angle of 25º and luminance of approximately 400 cd/m^2 was used. The stimulus was projected with an LCD projector; its luminance was modulated by a liquid-crystal shutter controlled from a PC running Presentation software.

fMRI experiments were performed on a 3.0 T GE scanner, equipped with 16-channel head coil and receiver system (Nova Medical, Inc.). The functional data were acquired with gradient echo rate-2 SENSE EPI [2] with the following parameters: TE/TR=40/1000 ms, flip angle=70°, 8 slices, resolution=1.5 x 1.5 x 3.0 mm^3. MEG experiments were performed on a 275-channel whole-cortex system (CTF, Inc.). Data acquisition rate was 600 Hz. The stimulus light signal was recorded with the brain signals to facilitate data analysis (ADC16 in Fig. 2). Reference coils were used to allow registration with fMRI data. Synthetic aperture magnetometry (SAM) [3] was used to localize the activation site.

For fMRI data analysis, activated pixels were determined from a regression analysis using the stimulus paradigm and a modelled impulse response. For each frequency, the BOLD activation signal was averaged over all blocks. The response was averaged over all pixels whose t-scores exceeded 4.8-5.2 (p=0.05) at any frequency. For MEG data analysis, blocks of the individual frequency were averaged and time-frequency analysis was performed to extract signals in the frequency band (6 Hz width) of the stimulus, as well as higher order harmonics. Physiologic noise was subtracted in magnitude mode using the rest periods. The 1st and 2nd harmonics were root-sum-of-squares combined and the 6 strongest occipital channels were averaged. For both fMRI and MEG data, response amplitudes were scaled to a maximum of 1.

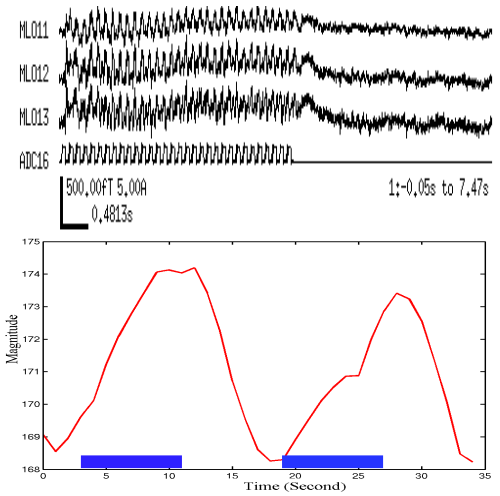

Fig. 2: **top**: Example of an 8 Hz MEG response, averaged over 40 blocks. The stimulus intensity is shown in the bottom trace (ADC16). **bottom**: Example of 2 blocks of an 8 Hz fMRI response (red), averaged over the active area. Stimulus (blue) duration is 8 seconds for each block.

Results and Discussion:

MEG and fMRI showed activity in similar brain regions in early visual areas (primarily V1). Fig. 1 shows an example of fMRI and MEG visual cortex activity (8 Hz) superimposed on the inflated left cerebrum. Fig. 2 shows an example of MEG and fMRI time courses. The average frequency response for MEG and fMRI (Fig. 3) showed a peak response at about 10 Hz. In individual subjects, the optimum response occurred at frequencies ranging from 8-12 Hz. This result is consistent with earlier fMRI studies [4,5] and a combined fMRI/EEG study [6].

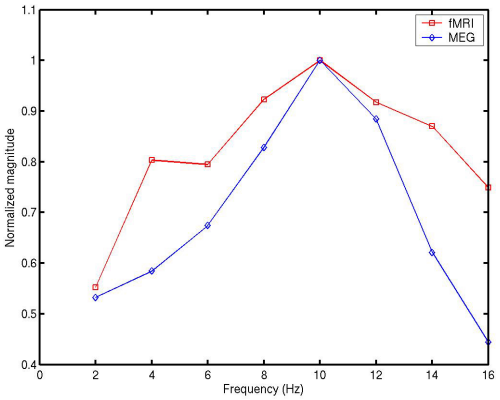

Fig. 3: Comparison of the 5-subject average MEG and fMRI visual response as a function of frequency.

Conclusions:

A strong correlation was found between MEG and fMRI measures of visual flicker induced brain activity, both in location and in amplitude. Although the fMRI amplitude response has a somewhat broader "tuning" curve, both MEG and fMRI have a maximum at 10 Hz.

References:

[1] Logothetis NK, et al. Nature 2001, 412:150-157. [2] de Zwart JA, et al. Magn Reson Med 2002, 48:1011-1020. [3] Robinson SE ,et al. Biomag 98, 11th Int. Conf. On Biomagnetism, 1998, Sendai, Japan: 1-4. [4] Thomas CG, et al. Magn Reson Med 1998, 40: 203-209. [5] Hagenbeek RE, et al. Human Brain Mapping 2002, 17:244-250. [6] Singh M, et al. Magn Reson Med 2003, 49:108-114.