FMRI/MEG studies of the visual 3D structure perception

S. Iwaki[1,2], G. Bonmassar[1], J. W. Belliveau[1]

[1]Massachusetts General Hospital, Charlestown, MA, United States, [2]National Institute of Advanced Industrial Science and Technology, Ikeda, Osaka, Japan

Introduction

Recent neuroimaging studies suggest the involvement of the parieto-occipital junction, the superior-occipital gyrus, and the ventral occipito-temporal junction in the perception of 3D structure from motion [1]. However, the neural dynamics underlying the reconstruction of a 3-D perception from optic flow is not fully understood. Here, we used both the neuromagnetic (MEG) and the hemodynamic (fMRI) measurements to detect the dynamic brain responses to 3-D structure perception from random-dot motion in humans.

Methods

Eight normal right-handed subjects participated in the study. The visual stimuli consisted of 1000 random dots, which started to move 500 ms after the onset of presentation. The coherence of the motion was controlled from 0 to 100 %. A stimulus that is fully coherent has all the dots moving as if they belonged to a rotating spherical surface with a radius of 10 degree in visual angle. On the other hand, the 80, 60, 40, 20, and 0 % coherence stimuli contain dots having the same speed as the fully coherent stimuli but the directions of the 20, 40, 60, 80, and 100 % of the dots were randomized, respectively.

MEG signals were measured during subjects viewing visual stimuli with a 306-channel system. The stimulus-related epochs of 2000 ms, including a 1000 ms pre-stimulus baseline, were recorded at a sampling rate of 600 Hz. More than 60 epochs were averaged for each condition. The fMRI scanning was conducted using a 3 Tesla Siemens Allegra scanner. For functional imaging, the single shot echo-planer imaging sequence was used with the imaging parameters TR 3000 ms, TE 40 ms, FA 90 deg, 40 axial slices, 3 mm thickness with 0 mm gap, 64x64 matrix, and FOV 220 mm, which covered the entire brain. Three 14-min functional scans were divided into 12 sec phases, randomly alternating between different stimulus (coherency) conditions and resting (fixation) periods. Within each phase, motion stimuli were presented every 4 sec.

Reconstruction and analysis of the fMRI data were performed using FreeSurfer and SPM software. The results of the fMRI analysis were used to impose plausible constraints on the MEG inverse calculation using a 'weighted' minimum-norm approach [2] to improve spatial resolution of the spatiotemporal activity estimates. In this study, we included fMRI weighting (determined by thresholding the fMRI statistical parametric map for each condition vs. fixation condition) into a linear inverse operator used to map the measured MEG signal into estimated neural source distributions in the cortex [3].

Results and Discussion

Subjects responses collected during the MEG measurements showed that the perception of 3-D structure (rotating sphere) was dominant only in the 80 and 100 % coherence conditions.

Fig. 1 shows fMRI statistical parametric maps for 3D perception condition (100 and 80 % coherence) vs. random motion condition (0 and 20% coherence) obtained using inter-subject random effect analysis. Activation in the occipito-parietal and intra-parietal regions was modulated by the change of motion coherence. Fig.2 shows the neural activity distributions for (a) the random motion condition and (b) the 3-D perception condition estimated using fMRI-constrained MEG inverse procedure in the typical subject. The bilateral occipito-temporal and the intra-parietal regions showed increased neural activity in the fully coherent motion condition around the latencies of 180 ms and 240 ms after the onset of motion, respectively.

These results indicate that the bilateral occipito-temporal, occipito-parietal and intra- parietal regions play an important role in the perception of 3-D structure from random-dot motion. Our data are in agreement with those from the previous studies of 3-D perception from motion using fMRI, and adding the further insight into the temporal characteristics of the neural activities in these regions. The change in the activation in the occipito-temporal motion- sensitive area in conjunction with the perception of global motion is also reported in the previous fMRI studies, and the intra-parietal region were reported to be activated during the mental imagery processing [4], which suggests that the perception of moving 3-D object from 2-D random-dot motion includes both perception of global motion and 3-D mental image processing. Spatiotemporal data suggest this is accomplished by the cooperative activation in the ventral and dorsal visual pathways.

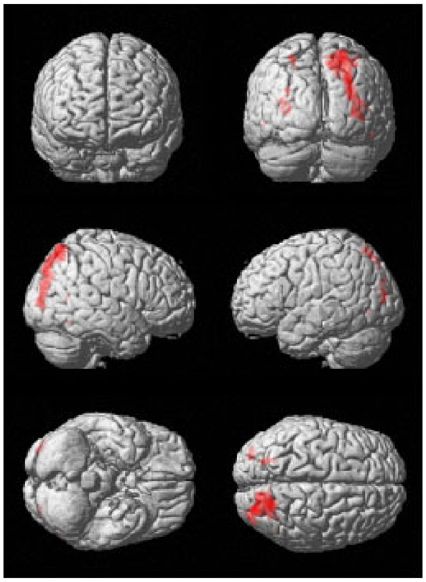

Fig. 1 Results of the fMRI inter-subject comparison between 3-D perception condition and 2-D perception condition.

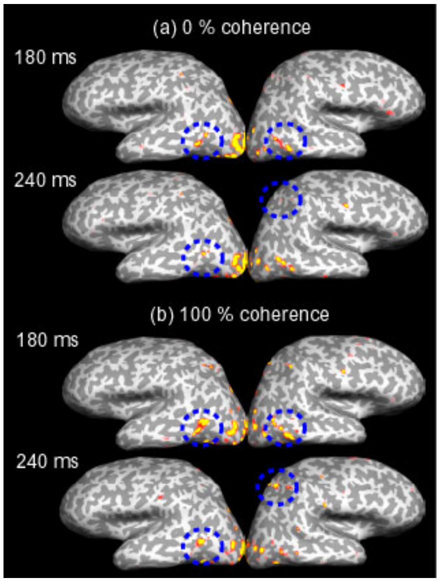

Fig. 2 Neural activity distribution estimated using MEG-fMRI combined spatiotemporal imaging for (a) the random-dot motion condition and (b) the fully coherent motion condition.

References

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