Visualization of the dynamic neural activity during the perception of 3-D structure from random dot motion: An fMRI-MEG combined study

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Introduction

Perception of 3-D structure from motion requires the visual motion to be integrated spatially as well as the recognition of the object shape. Many psychophysical studies have been done to investigate how the visual system extracts the 3-D structure of objects from 2-D motion of random dots (structure-from-motion: SFM). 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], though 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 human.

Methods

Visual stimuli: 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 had 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 experiment: Neuromagnetic signals were measured during subjects viewing visual stimuli with a 306-channel MEG system. The stimulus-related epochs of 2000 ms, including a 1000 ms pre-stimulus baseline, were recorded with a pass-band of 0.01 - 200 Hz and a sampling rate of 600 Hz. More than 60 epochs were averaged for each condition.

fMRI experiment: The 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.

Data Processing: Reconstruction and analysis of the fMRI data were performed using FreeSurfer software. The data were realigned using the first image as a reference and spatially smoothed using Gaussian kernels of 6 mm. A boxcar wave function was applied as a reference function, and a statistical parametric map was generated for each voxel. The results of the fMRI analysis were used to impose plausible constraints on the MEG inverse calculation using 'weighted' minimum-norm approach [2] to improve spatial resolution of the spatio-temporal activity estimates. In this experiment, we introduced fMRI weighting, which was determined by thresholding the fMRI statistical parametric map for each (0, 20, 40, 60, 80, and 100 % coherence) condition vs. fixation condition, into linear inverse operator used to map measured MEG signal into estimated neural source distributions [2].

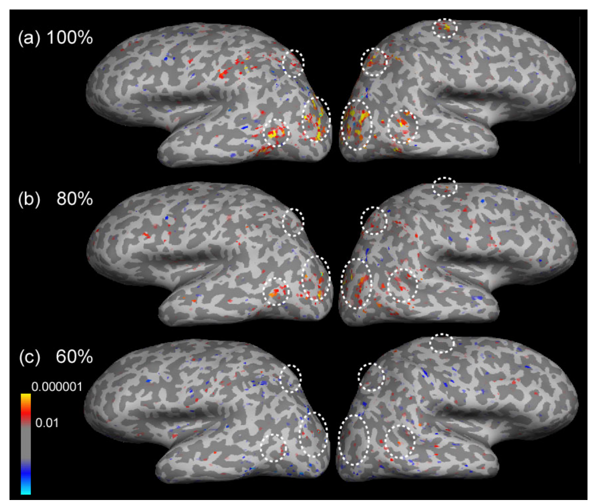

Fig. 1 Results of the fMRI analysis for coherent motion ((a) 100, (b) 80, and (c) 60 % coherence) conditions vs. random-dot motion (0 % coherence) condition

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 coherent motion ((a) 100, (b) 80, and (c) 60 % coherence) conditions vs. random-dot motion (0 % coherence) condition in the typical subject. Activation in the bilateral occipital/occipito-temporal and the intra-parietal regions were modulated by the change of motion coherence. Fig.2 shows the neural activity distributions for (a) the random-dot motion condition and (b) the fully coherent motion 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 and intra-parietal regions play an important role in the perception of 3-D structure from random-dot motion. Also, the present study adds further insight into the temporal characteristics of the neural activities in these regions.

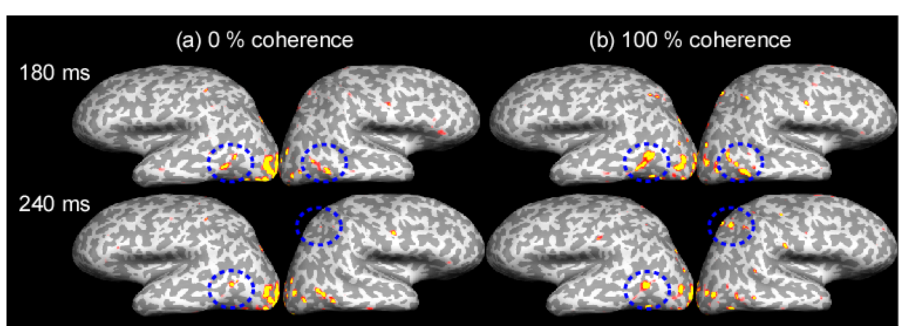

Fig. 2 Neural activity distribution estimated using MEG-fMRI combined spatio-temporal imaging for (a) the random-dot motion condition and (b) the fully coherent motion condition.

References

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[2]Dale A.M. *et al.*, *Neuron* **26**: 55-67, 2000.