Cortical Regions Involved in Navigation

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Introduction

Continuous visuospatial navigation in familiar and unfamiliar environments is a requirement of daily life. It is also one of the few cognitive functions for which a reliable gender-specific performance difference is well known (1,2). To investigate the neural basis of gender differences in maneuvering through unfamiliar environments, we used functional magnetic resonance imaging (fMRI) while male and female subjects navigated through totally unknown three-dimensional mazes.

Methods

A virtual reality (VR) maze (Fig. 1) was modelled and programmed for user interaction on a PC. User interaction in the MR scanner was made possible by means of a specially designed MR-compatible keyboard working with fibre optics.

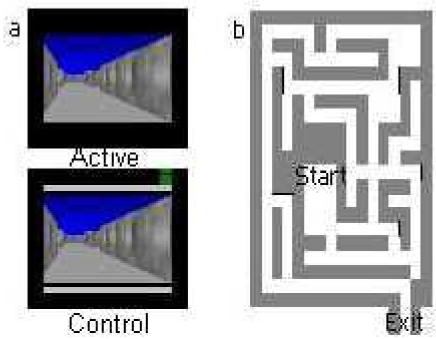

Fig. 1. VR maze. a) Subject´s view, b) map.

24 healthy subjects (12m, 12 f) were scanned with fMRI during finding their way out of the maze. Navigating through the maze was interrupted by a reaction task as control condition. fMRI scans were taken on a Siemens magnetom vision scanner (Siemens Corp., Iselin, NJ) using a single-shot EPI sequence with 780 Hz/pixel bandwidth. Scanning parameters were FA/TE/TR 90°/66/4300 ms, 64x64x32 voxels, FoV 230 mm, 3 mm slice thickness with 0.6 mm gap, resulting in isotropic voxels of 3.6 mm resolution. The fMRI protocol was a block design with alternating epochs of navigation and reaction task. Each epoch lasted 21.5 s (equivalent to 5 whole-brain fMRI volume acquisitions). The first six volumes in each session were discarded to allow for T1 equilibration effects.

Image processing and data analysis was performed by Statistical Parametric Mapping (Wellcome Institute of Neurology, London). fMRI volumes were corrected for motion by realigning to the first volume of each run and resliced using sinc interpolation. For group analysis, data were spatially normalized to a standard brain template. Z-statistics for each and every voxel were thresholded at $p<.01$ for the group analysis. The level of significance for inference of activated voxel clusters was $p<.05$.

Results

The analysis of the whole group revealed bilateral activity of the medial occipital gyri, the lingual gyri, the parahippocampal gyri and the right hippocampus proper, the posterior cingulate and the superior colliculi, as well as medial and lateral superior parietal lobules (Fig. 2).

To analyze gender differences, we analyzed male and female subjects separately. As expected from the group analysis, there was a great overlap in neural activity between both groups. However, in the differential analysis, which contrasts one group against the other, we observed a clear cut locally dissociating pattern. Women showed the left superior frontal as well as the right medial frontal gyrus (Fig. 3a) in addition to the common network, whereas men activated the left parahippocampal gyrus and the left hippocampus proper (Fig. 3b).

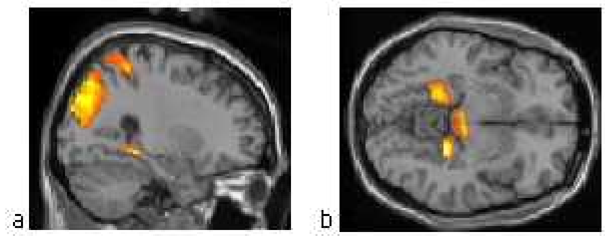

Fig. 2. Group analysis men + women.

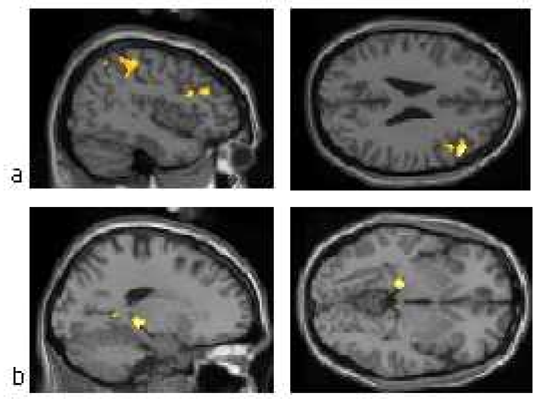

Fig. 3 Differential analysis. a) Women minus men, b) Men minus women.

On the behavioral level, men were significantly faster than women finding a way out of the maze (mean runtime of the male group, 141.8 ± 31.9 s; mean run-time of the female group, 196.1 ± 26.6 s; $t22 = -4.97$; $p < 0.001$).

Discussion

We demonstrated that navigation can be studied by fMRI using VR tools. Our behavioral data are in line with the results of other groups (1,2). We found differences in brain activation during maze navigation between men and women (3) which suggest gender differences in navigation strategies (4).

References

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