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Neural correlates of visuospatial perspective taking

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Background

The ability to take the viewpoint of someone else is a constitutive part of spatial and putatively social cognition. A basic requirement is the translocation of the egocentric viewpoint from one´s own first person perspective (1PP) to a third person perspective (3PP) of another person. Previously, Vogeley and colleagues showed a network essentially consisting of superior parietal and premotor areas to be involved in these cognitive operations (Vogeley et al 2004).

We have modified the original paradigm in order to make it suitable for addressing visuospatial perspective taking in neuropsychiatric patients. This included a reduction of experimental length as well as the introduction of a training session. Thus, the first aim of this study was to replicate the results with this modified paradigm. In addition, we wanted to investigate the effects of gender on neural activity in this spatial perspective taking task, since gender differences in spatial cognition have repeatedly been described.

Methods

22 healthy subjects (11 male / 11 female, mean age 26.6y / 28.4y) participated in the study. A virtual scene with an avatar and red balls was presented from different camera viewpoints in a ground view position. In a blocked design participants were either required to count the objects as seen from their own (1PP) or from the avatars perspective (3PP). Images were acquired on a Siemens Trio 3T scanner. Using echo-planar imaging functional images covering the whole brain including the cerebellum with isotropic voxels were acquired with the following parameters: 48 slices of 3.1mm thickness, matrix size 64x64 with 3.1x3.1mm in-plane resolution, TR 4000msec, TE 60ms, 90° flip angle. In addition, a high resolution sagittal T1 weighted image was acquired.

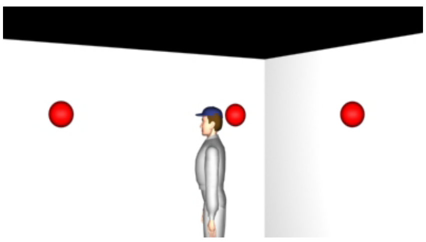

Figure 1: Participants were presented with the image of a room including an avatar and one to three red balls. In the 1PP condition patients were required to number the balls they could see, while in the 3PP they were asked to number the balls the avatar could see from his perspective.

Data analysis was performed with SPM2. After standard preprocessing procedures functional images were normalized to the MNI templated and smoothed with a kernel of 10mm FWHM. Using the general linear model t-contrasts for 3PP vs 1PP were computed for each subject. Using SnPM2 the contrast images were entered into a nonparametric permutation test without variance smoothing. Reported p-values are corrected at $p<0.05$ for the whole brain.

Results

Behavioral data are shown below. A significant interaction between group and condition was found for correctness. Post-hoc testing showed that female participants differed significantly between conditions, but groups did not differ significantly for any condition.

	Male		Female		Interaction Test	
	3PP	1PP	3PP	1PP	F (1,20)	p
Reaction Time (ms)	1012 ± 248	881 ± 226	1052 ± 117	971 ± 87	1.84	0.19
Correctness Score (%)	93.0 ± 3.8	95.4 ± 4.3	91.0 ± 5.5	97.4 ± 1.7	4.62	0.04

Table 1: Behavioural data for both groups and conditions

Group activation maps and respective tables for each group (male/female) are shown below. The direct comparison between groups did not reveal any significant differences at whole brain corrected p-values.

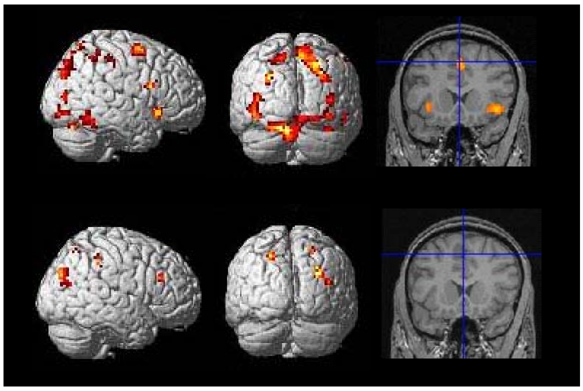

Figure 2: SnPM t-maps for male (upper row) and female participants (lower row) thresholded at $p<0.05$ corrected. T-maps are rendered on the SPM single subject template (left) or overlaid on the T1 weighted structural image of one participant (right).

Region	Cluster Size	T	X	Y	Z
Left Lingual Gyrus	**354**	**15.01**	**- 18**	**- 78**	**- 15**
Left Cerebellum		13.23	-9	-87	-21
Right superior frontal gyrus	**70**	**13.93**	**30**	**0**	**60**
Right fusiform gyrus	**187**	**12.29**	**33**	**- 42**	**- 21**
Right inferior temporal gyrus		10.78	45	-48	-21
Right inferior parietal gyrus	**315**	**12.10**	**30**	**- 54**	**48**
Right Precuneus		11.78	9	-75	45
Right lingual gyrus	**28**	**11.56**	**12**	**- 45**	**0**
Left middle occipital gyrus	**99**	**11.34**	**- 42**	**- 75**	**3**
Right insula	**54**	**11.12**	**42**	**18**	**-9**
Right cerebellum	**20**	**11.00**	**33**	**- 69**	**- 24**
Left middle occipital gyrus	**40**	**10.83**	**- 27**	**- 75**	**- 33**
Right middle occipital gyrus	**22**	**10.41**	**39**	**- 81**	**9**
Right anterior cingulate gyrus	**67**	**10.30**	**6**	**27**	**30**
Left precuneus	**45**	**9.38**	**- 12**	**- 69**	**57**

Table 2: Activation foci 3PP vs 1PP for male participants

Region	Cluster Size	T	X	Y	Z
Right inferior frontal gyrus	**12**	**10.78**	**48**	**30**	**27**
Right middle occipital gyrus	**51**	**10.51**	**30**	**- 78**	**33**
Left superior parietal gyrus	**19**	**10.37**	**- 21**	**- 69**	**48**
Right superior parietal gyrus	**11**	**8.33**	**24**	**- 63**	**54**
Right inferior parietal gyrus	**14**	**8.25**	**48**	**- 39**	**45**
Right middle temporal gyrus	**13**	**8.08**	**42**	**- 72**	**21**

Table 3: Activation foci 3PP vs 1PP for female participants

Discussion

The results for our male participants are consistent with the original study (Vogeley et al. 2004) and show activation of a network essentially involving th superior parietal and the premotor regions during 3PP. However, some interesting differences should be noted. In the present study, activation was more widespread in occipital areas involving the lingual gyrus, which has been shown to be activated when body motions are observed or imitated from 3PP as opposed to 1PP (Jackson et al 2006). Foci in bilateral middle occipital gyrus in close proximity to the extrastriate body area were also found (Astafiev et al 2004). In addition, activity in anterior medial prefrontal cortex was found, which is often involved in classical "theory of mind" tasks but was notably absent in the previous study (Gallagher and Frith 2003).

With respect to gender, no significant differences between female and male participants emerged. This seems surprising, because in spatial tasks differences in performance as well as activation patterns have consistently been reported (Halari et al 2006). However, female participants showed fewer significantly activated voxels. Inspection of the single-subject data suggests more heterogeneous activation patterns on the individual level.

In conclusion, the study was replicated after reducing the amount of stimuli at 3T field strength and showed additional activation sites including the lingual gyrus, presumably the extrastriate body area and the anterior medial prefrontal cortex. These activations suggest that taking 3PP in the present tasks involves representing the avatar as a human agent.

References

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