

TITLE

Neural bases of perspective differences in theory of mind tasks: A meta-analysis of neuroimaging studies.

AUTHORS

Schurz, M., Aichhorn, M., Perner, J.

Introduction

Functional neuroimaging research suggests that different neuro-cognitive processes are contributing to theory of mind reasoning (e.g., Saxe & Young, in press). Studies from our group suggested that, in addition to the processing of mental states, theory of mind reasoning sometimes also engages the processing of a perspective difference, which is related to activation in the left temporo-parietal junction (e.g., Aichhorn et al., 2006, Perner et al., 2006). A well-known example for a task which engages processing of perspective differences is the false belief task, which requires distinguishing between the false belief of a protagonist and one's own view of reality. Based on a graphical summary of imaging studies, Perner & Leekam (2008) observed that theory of mind tasks that present a perspective difference (e.g. understanding false beliefs of others) activate a different portion of the left temporo-parietal junction compared to tasks that do not present a perspective difference (e.g. assess mental dispositions of others). In contrast, both groups of tasks activated roughly the same portion of the right temporo-parietal junction. In the present study, we performed a meta-analysis on brain imaging findings to provide a quantitative evaluation of the observations of Perner & Leekam (2008). In addition, we compared brain activation for theory of mind tasks to brain activation for other groups of tasks which may involve processing of perspective differences, in particular episodic memory or mental rotation tasks.

Methods

We conducted a quantitative, effect-size based meta-analysis using the SDM software (<http://sdmproject.com>, Radua et al., 2011). For each group of studies, we calculated a meta-analytic map at an uncorrected threshold of $p < .001$ and a minimum cluster size of 10 voxels. In a first step, we performed a meta-analysis on neuroimaging studies on theory of mind reasoning. We separated studies into those presenting theory of mind tasks which create a perspective difference and those presenting theory of mind tasks which do not create a perspective difference. A statistical comparison between the meta-analytic maps for the two groups of studies was performed by calculating a linear contrast (see Radua et al., 2011). In a second step, we performed meta-analyses of neuroimaging studies on episodic memory and mental rotation. Areas commonly activated by processing of perspective differences in theory of mind tasks and episodic memory or mental rotation tasks were determined by conjunction analyses in SPM8 (<http://www.fil.ion.ucl.ac.uk/spm/>).

Results

Consistent with recent reviews (e.g., Mar, 2011; Saxe & Young, in press), our meta-analysis found the medial prefrontal cortex and the bilateral temporo-parietal cortices reliably activated in theory of mind tasks. Tasks that did not require processing of a perspective difference predominantly activated ventral/anterior aspects of the temporo-parietal cortices, in particular the middle temporal gyri and the posterior superior temporal sulcus (see Figure

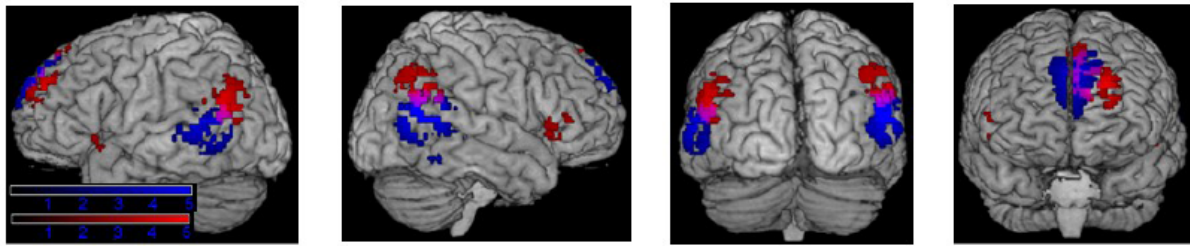
1A). In contrast, tasks that did require processing of a perspective difference (Figure 1B) activated more dorsal/posterior aspects of the temporo-parietal cortices, in particular the angular gyrus. A statistical comparison between the meta-analytic maps for tasks with and without perspective differences confirmed this task-dependent dissociation in terms of brain activation both for the left and the right temporo-parietal cortex (Figure 1C). A conjunction analysis between activation for theory of mind tasks presenting a perspective difference and activation for episodic memory tasks found an area of overlapping activation in the left temporo-parietal junction, with an activation peak in the left angular gyrus. No overlap was found for the right temporo-parietal junction. Results of the conjunction analysis between activation for theory of mind tasks presenting a perspective difference and activation for mental rotation tasks were less clear cut.

Conclusion

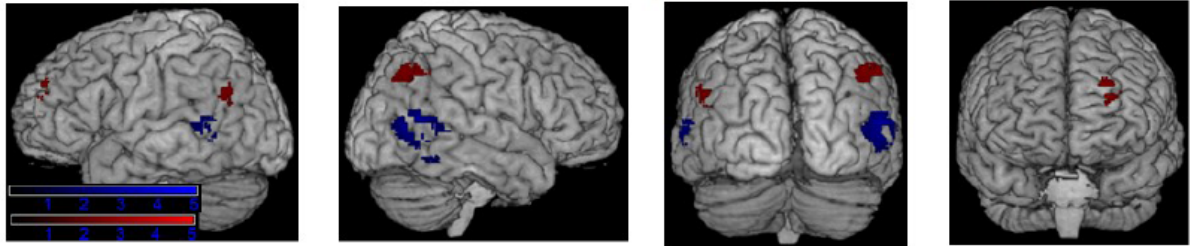
Results from our meta-analysis are consistent with the idea that more dorsal aspects of the left temporo-parietal junction, in particular the left angular gyrus, are engaged in the processing of a perspective difference in theory of mind tasks. The overlap in activation with episodic memory tasks reinforces the idea of Aichhorn et al. (2006) and Perner et al. (2006) that **processing of perspective differences is not a process specific for theory of mind reasoning, but a common element of tasks that require sensitivity to perspective**. For example, it was argued that the remember/know decision often used in episodic memory tasks requires participants to distinguish between the perspective experienced in the recollection and the event in the past of which it provides a perspective (e.g., Perner, Kloo & Stöttinger, 2007; Perner, Kloo & Rohwer, 2010). Of further interest, the overlap in brain activation for tasks presenting a perspective difference was clearly restricted to the left hemisphere. Activation in the right temporo-parietal junction was only found for the domain of theory of mind. This is compatible with the idea that the right temporo-parietal junction is specialized for processing of mental states (e.g., Saxe & Kanwisher, 2003; Saxe & Wechsler, 2005).

Meta-Analytic Results

A. Theory of mind with perspective (red), theory of mind without perspective (blue), and areas of overlap (purple).



B. Statistical comparisons of activations in A. Red: with > without perspective, blue: without > with perspective.



C. Theory of mind with perspective (red), episodic memory (blue), and areas of overlap (purple).

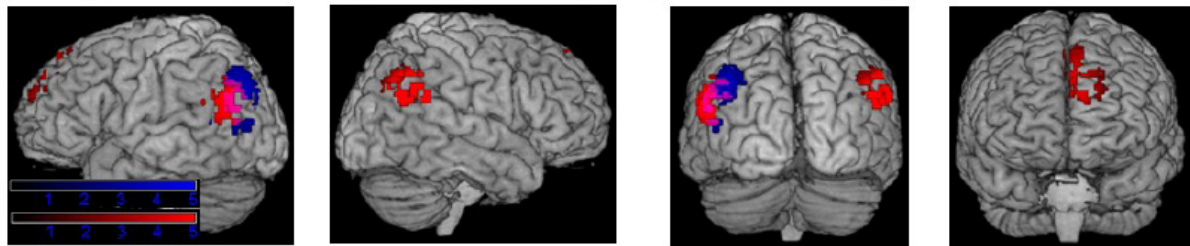


Figure 1. (A) Overlay of activation for theory of mind studies that did (red) or did not (blue) require processing of a perspective difference. (B) Results of a statistical comparison between activation for theory of mind tasks that did or did not require processing of a perspective difference. (C) Overlay of activation for theory of mind tasks that did require processing of a perspective difference and activation for episodic memory tasks. All maps are displayed at an uncorrected threshold of $p < .001$ and a minimum cluster extent of 10 voxels.

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