See it from my side! A fMRI study of perspective-taking using language

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Introduction

In spatial cognition, a distinction is drawn between an egocentric and allocentric frame of reference (Vogeley & Fink 2003). Using event-related functional magnetic resonance imaging we investigated the BOLD responses to varying this reference frame when hearing spoken descriptions of spatial scenarios in which subjects adopted a first-person egocentric frame of reference (e.g. *He is running towards you*) or an allocentric frame of reference (e.g. *She is standing behind him*). Pseudo sentences and nonsense sentences were included as control stimuli.

We asked the question whether auditory linguistic descriptions containing information about frame of reference automatically activate brain regions previously found to be related to perspective-taking or whether it requires subjects attend to this aspect of the stimuli to adopt a particular frame of reference. In other words, whether it requires a particular attentional set.

Methods

20 Danish right-handed healthy volunteers, 11 women, 9 men, mean age 23 (range 20-35) were scanned with T2*-weighted echo-planar imaging in a 3.0 T General Electric MRI scanner using the following parameters: repetition time (TR) = 3 s, echo time (TE) = 30 ms, flip angle = 90°, field of view = 240 mm^2 and in-plane resolution = 128×128 pixel matrix.

Subjects were scanned in three sessions that all included the same set of auditory stimuli, but each with a different cognitive task. In task A subjects judged whether the described scenario involved motion. In task B subjects were required to explicitly adopt a first-person egocentric or an allocentric frame of reference. In task C subjects judged whether the sentences made sense or not. In this way each cognitive task induced a different attentional set in the subject with which the exact same stimuli were perceived. Stimuli and scanning sessions were randomized within and across subjects.

Functional images were analyzed with SPM5 using a general linear model (Friston et al 1995). For each subject a first-level model was constructed modelling both stimulus and task-related responses as an event-related stick function convolved with a canonical hemodynamic response function. In this way, BOLD responses were estimated for the 2×2 experimental conditions: egocentric motion, allocentric motion, egocentric stationary scenario, allocentric stationary scenario. A second-level model was created for each session using the beta-weighted images from the first level in an analysis of variance (ANOVA) modelled in SPM as a factorial design. In this way a random-effects analysis was performed to allow inferences at the population level (Friston et al 1999). All contrasts were thresholded at $p<0.05$, using a false discovery rate (FDR) whole-brain correction (Nichols 2006). Anatomical regions were localized in MNI space using the Wake Forest University Pickatlas (Maldjian et al 2003, 2004).

Results

Behavioural response times between egocentric and allocentric conditions showed a significant task-by-perspective interaction: when subjects heard sentences describing an egocentric scenario and the task was to explicitly adopt an first-person egocentric reference frame, response times were faster than for allocentric scenarios where subjects adopted an allocentric frame of reference. Interestingly, this behavioural difference was directly reversed in the other cognitive tasks, where subjects responded significantly faster for allocentric scenarios. However, a behavioural post-scan study using the exact same stimuli and tasks in interleaved and randomized order showed no differences in response times and hence no observable differences in task difficulty.

fMRI data showed a significant task-by-perspective interaction that mirrors the initial response time interaction: when subjects heard sentences describing an egocentric scenario and the task was to explicitly adopt a first-person egocentric perspective versus an allocentric perspective, increased BOLD activation was observed at the left temporoparietal junction, posterior cingulate cortex and medial prefrontal cortex. The peak voxels in all three clusters were located in the left hemisphere.

There were no significant voxels in the allocentric>egocentric contrast and no main effect of motion. Moreover, there was no main effect of perspective or motion in the remaining sessions at $p<0.05$, FDR-corrected.

Conclusion

Using auditory linguistic descriptions as stimulus modality with which we compare egocentric and allocentric reference frames, we observe left-hemispheric activation in the posterior temporal cortex at the temporoparietal junction, posterior cingulate cortex and medial prefrontal cortex, but only when subjects attend to perspective. The same regions were activated bilaterally during first-person visuospatial perspective-taking versus third-person perspective-taking by Vogeley et al (2004). These results suggest that auditory linguistic stimuli containing information about frame of reference are not enough to evoke brain activity in regions related to spatial perspective-taking. It requires a particular attentional set. Given that all subjects were right-handed and native Danish speakers, we speculate that the auditory language modality of the stimuli plays a role in the left-lateralized activation of this cortical network.

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