PERSISTENT ACTIVITY IN POSTERIOR PARIETAL CORTEX REFLECTS PLANNED CHANGES IN ORIENTATION DURING NAVIGATION

Peter Brotchie[1,2], Shaun Seixas[3], Shoane Ip[4], Mathew Hughes[3], and Graeme Jackson[4]

[1]MRI, Geelong Hospital, Geelong, Victoria, Australia, [2]Radiology, University of Melbourne, Melbourne, Victoria, Australia, [3]Brain and Psychological Research Centre, Swinburne University of Technology, Melbourne, Victoria, Australia, [4]Melbourne Brain Centre, Brain Research Institute, Melbourne, Victoria, Australia

Introduction

Topographical disorientation is a term describing deficits in the ability to navigate and clinical data implicates 3 main cortical regions that can produce different forms of this disorder (Aguirre & D'Esposito, 1999). These regions are the parahippocampal cortex, the retrosplenial cortex and the posterior parietal cortex. Patients with damage to the parahippocampal cortex have difficulty representing environmental stimuli such as visual landmarks and damage to the retrosplenial cortex is associated with difficulties in orienting to the environment. Clinical studies suggest that damage to the posterior parietal cortex causes egocentric disorientation or an inability to represent the location of objects with respect to oneself. Both the parahippocampal cortex and the retrosplenial cortex have been well studied in functional MRI tasks. The parahippocampal place area becomes activated on viewing visual scenes (Epstein 2008). The retrosplenial cortex, also known as the posterior cingulate, is also activated on viewing visual scenes but is more strongly activated if the scenes contain familiar landmarks (Epstein 2008) and may be using the information to encode heading direction (Baumann & Mattingley, 2010). However, the role of the third region, the PPC, has not been well established with functional imaging. One feature of PPC that has been revealed by single cell recording studies in primates is the existence of persistent neuronal activity. Persistent activity is evident in neurons in a number of regions of the brain, best demonstrated in delayed response tasks. In PPC, persistent activity is also called planning activity and reflects upcoming planned actions (Whitlock et al, 2008). In this study we have used long interval repetition suppression with a delayed response paradigm to demonstrate persistent activity in PPC that is orientation specific and reflects a planned change in orientation within the environment during navigation.

Methods

Paradigm:

We imaged 2 groups (A and B) of participants in a simple navigation task looking at the effects of a change in orientation of a visual landmark relative to the observer. The task consisted of a 3D virtual environment in which a single visual landmark was visible. The participant viewed the landmark from a starting orientation positioned to the side of the landmark at the start of each trial. After a delay period of 3 to 6 seconds, signaled by a dot changing colour, the subjects pressed a mouse button to rotate right or left to face the landmark straight on.

For the Group A participants, the starting orientation was different for each trial so that there was no chance for repetition suppression to occur. In a quarter of the trials, the starting orientation was the same as the target orientation so no button press was required (No Move Condition). In the remaining trials the starting orientation was randomly selected and different from the target location, requiring a button press to complete the task (Move Condition). In the Move Condition, the starting orientation was either rotated leftward (Left Move Condition) or rightward (Right Move Condition) from the target orientation.

In the Group B participants, three quarters of the trials started from the exact same orientation so that suppression effects would be maximized (Control Condition). In one quarter of the trials, the starting orientation was randomly shifted (Shifted Condition). The trials with a shifted orientation were never repeated so that neuronal suppression would only exist in the non-shifted trials. In half of the shifted trials, the starting orientation was the same as the target orientation so no button press was required (No Move Condition).

Imaging:

BOLD imaging was performed on a 3 tesla Siemens Trio MRI scanner at Geelong Hospital, Geelong, Australia (Group A) and a 3 tesla GE MRI scanner at the Brain Research Institute in Melbourne, Australia (Group B). 21 images were acquired through the cerebral hemispheres. T1 weighted images were acquired for anatomical localisation and a BOLD EPI sequence was acquired every 2.5 seconds during the paradigms.

Data Analysis

The dataset of each subject was analysed individually and with second level group analysis using SPM8 (Statistical Parametric Mapping, Wellcome Department of Cognitive Neurology, London, UK). 3D motion correction was performed on all image volumes within a single acquisition. For group analysis, images were registered into normalized space and smoothed with an 8mm kernel. The data was analysed as an event-related study, modeled with two explanatory variables for each of the conditions. The first explanatory variable was modeled as a short event, aligned at the onset of each trial, that is, when the subject first sees the landmark. The second explanatory variable was set to the duration of the delay period prior to the execution of the button press.

Results

Group A Data:

No statistically significant activity was detected between the Left Move Condition and the Right Move Condition.

No statistically significant activity was detected between the Move Condition and the No Move Condition in parietal cortex.

As expected, when comparing the Move Condition with the No Move Condition, increased activity was seen in the motor planning regions bilaterally and reduced activity was seen in the ipsilateral primary motor cortex.

Group B Data:

When comparing the Shifted Condition with the Control Condition in the delay period, statistically significant clusters of activity ($p<0.05$ FWE) were seen within the posterior parietal cortex bilaterally (area PFm), predominantly on the left (Figure 1).

When comparing the Control Condition with the Shifted Condition in the delay period, a cluster of activity ($p<0.05$ FWE) was seen in the retrosplenial complex (RSC) (Figure 2).

In the onset period, a cluster of activity was seen in RSC when subjects were in the shifted location.

When comparing the No Move Condition to the Control Condition in the delay period, no significant increase in activity was seen within PPC.

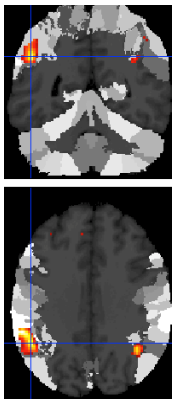

Figure 1

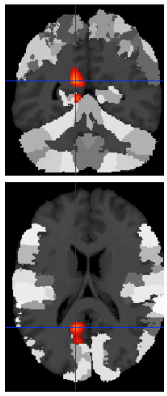

Figure 2

Discussion

The activity within RSC that we observed at the onset of trials in the Shifted Condition using repetition suppression for orientation confirms a recent report suggesting that this region encodes heading direction or at least detects heading direction after viewing known visual landmarks. However, in the delay period of the Shifted Condition, activity is no longer seen in RSC but is detected within PFm of the PPC. Since the activity is only seen by utilizing repetition suppression of the subject's orientation within the environment, this activity must also reflect orientation. However, as the activity is not replicated in the No Move condition, it is not simply reflecting orientation within the environment but also a plan to change orientation. PPC is a region known to contain neurons with persistent activity. Since this activity has been shown in single cell recording studies to reflect spatial coordinate transformations related to upcoming events, it follows that the activity we are seeing is reflecting the necessary spatial coordinate transformations to prepare for the expected upcoming change in orientation.

References

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