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Differential fronto-parietal contributions to visual and motor imagery

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Abstract

Introduction

Mental imagery is a cognitive process crucial to human reasoning. Numerous studies have characterized specific instances of this cognitive ability, as evoked by visual imagery (VI) or motor imagery (MI) tasks. However, it remains unclear which neural resources are shared between VI and MI, and which are exclusively related to MI.

To address this issue, we have used fMRI to measure human brain activity during performance of VI and MI tasks. Crucially, we have modulated the imagery process by manipulating the degree of mental rotation necessary to solve the tasks. We focused our analysis on changes in neural signal as a function of the degree of mental rotation in each task.

Methods

Functional magnetic resonance images (Siemens SONATA, 1.5 Tesla,TR=2.56,32 slices,900 images) were acquired while six right-handed volunteers performed a mental rotation task on two sets of stimuli. When presented with line drawings of hands, subjects had to report whether the item represented a right hand by flexing either the index or the middle finger of their right hand. This task evokes first-person motor imagery (Parsons 1994). When presented with letter stimuli, subjects had to report whether the item represented a canonical letter or its mirror image by flexing the same fingers as above. This task evokes visual imagery (Shepard and Cooper 1982). Both sets of stimuli could be rotated from their upright form(0°) to 180° in 30° steps. Statistical analysis of both behavioral data and functional images considered main effects of Task (2 levels:MI,VI) and Angle (7 levels:0° to 180°,in 30° steps). Confounding factors like error trials, head-related movements and trial-by-trial variations in reaction times were also modeled. Inferences on the imaging data are based on inter-subjects conjunction analysis ($p<0.01$ FDR-corrected).

Results

Behavioral data show a significant effect of Task ($F(1, 5)=16.30$; $p=0.01$), Angle ($F(6,30)=28.96$; $p<0.001$) and a Task X Angle interaction ($F(6,30)=10.08$; $p<0.001$). Both tasks show significant linear ($F(1, 5)=42.42$; $p=0.001$) and quadratic ($F(1, 5)=19.36$; $p=0.007$) trends.

Imaging data showed differential parametric modulation of neural activity as a function of Angle along the intraparietal sulcus and the superior precentral sulcus (Figure 1). However, while parietal cortex responds to both MI and VI tasks, precentral cortex shows activity only during MI.

Conclusions

By exploiting a parametric approach, we have been able to dissociate neural responses specifically modulated by the imagery process from other task-related activities (stimulus encoding, response monitoring, button press).

Behavioral results suggest that subjects relied on VI and MI to solve the tasks.

We found that both parietal and precentral regions were involved in the MI process, showing significant Task X Angle interactions. However, their response patterns revealed different contributions to the imagery task. The intraparietal sulcus was responsive during both VI and MI, suggesting that this region deals with visual aspects of the MI process. In contrast, there was no response in the superior precentral sulcus during VI, but strong modulation of activity during MI. We infer that the precentral region is concerned with motor cognitive processes evoked by MI.

References

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Shepard RN, Cooper LA(1982) Mental images & their transformations. MIT Press,Cambridge(MA).