Meta-Analysis of the default mode network: Connectivity patterns for activations and deactivations

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Introduction

Regions belonging to the default mode network of brain function are widely recognized as exhibiting task-related decreases in activity across a range of paradigms [1,2]. The aim of this study was to (1) systematically identify regions of the default mode network in a large-scale, quantitative meta-analysis of previously published PET and fMRI studies, and (2) analyze the functional connectivity patterns of these regions without the constraints of resting state data or data acquired during a particular task. This was accomplished using the BrainMap database [3,4], which archives stereotactic coordinates in the functional neuroimaging literature.

Methods

Paradigm-independent deactivations from the literature were searched for within BrainMap (http://brainmap.org). The identified coordinates (3816 coordinates from 506 contrasts) were pooled using the activation likelihood estimation (ALE) meta-analysis technique [5,6]. This yielded a consensus image detailing the locations of the default mode network (Fig1.1). Regions of interest (ROIs) were constructed for each ALE cluster; these ROIs were then used to search BrainMap for experiments that reported task-related increases (not decreases) within the ROIs (Fig1.2). Whole brain sets of coordinates for the experiments were downloaded and meta-analyzed using ALE to create ROI-based coactivation images, which approximate what is known about the functional coactivations of a given region across a range of paradigms (Fig1.3). This procedure was reported for all regions in the default mode network. All ALE images were thresholded at $P<0.05$ (FDR-corrected).

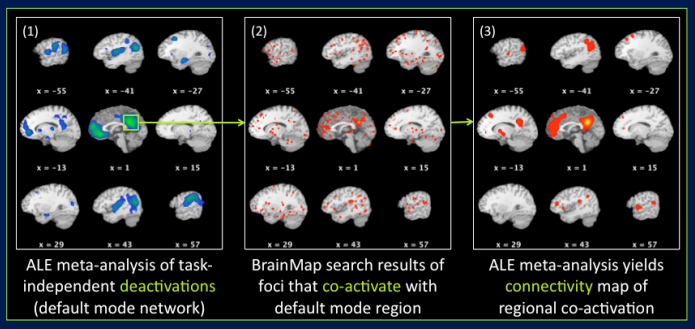

Figure 1. Task-independent patterns of activations and deactivations for regions in the default mode network were identified using ALE meta-analysis. Steps 2 and 3 are shown for the posterior cingulate cortex but were repeated for all regions in the default mode network.

Results

The ALE meta-analysis of deactivation coordinates revealed regions of convergence in areas known to be associated with the default mode network, such as the posterior cingulate cortex (PCC), ventral anterior cingulate cortex (vACC), precuneus, ventromedial prefrontal cortex, bilateral inferior parietal cortex, and bilateral amygdala. Analysis of the cognitive domains associated with the deactivations within BrainMap confirmed a uniform distribution across a wide range of paradigms. Coactivation analysis of the default mode regions revealed a dissociation between the activation and deactivation patterns; all coactivation images but one showed marked dissimilarity with the meta-analytic image of deactivations.

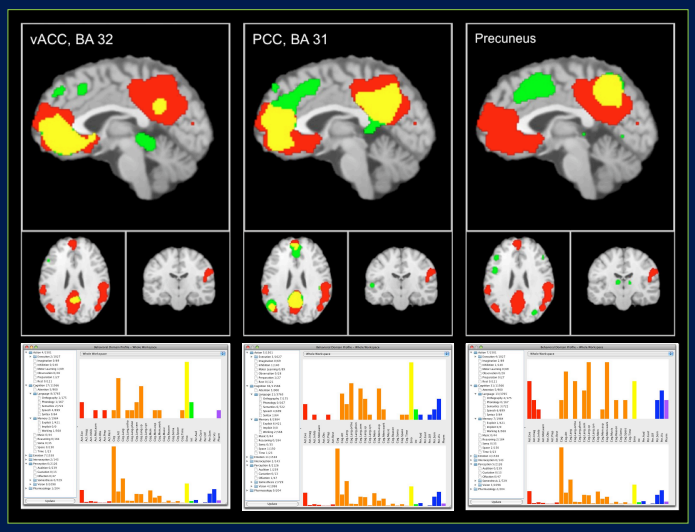

Figure 2. Task-independent patterns of activations and deactivations for the vACC, PCC, and precuneus. Large-scale deactivations meta-analysis shown in red; ROI-based coactivation map wshown in green (yellow-overlap). BrainMap behavioral histograms characterize the cognitive functional range associated with each region of interest.

Only the coactivation map obtained for the PCC exhibited extensive agreement with the deactivations image. Moreover, coactivation with the PCC was observed for every region in the default mode network. The dorsal ACC, was not identified in the deactivations meta-analysis; however it was present in all co-activation images. Unlike the results of the deactivations meta-analysis, histograms of the cognitive domains associated with the activations were not uniform; both the vACC and PCC were strongly loaded towards emotional processing, while the precuneus was strongly loaded towards attention, action, and working memory. The vACC also contained a strong loading in attention, while the PCC contained a relatively uniform spread in the attention, language, and memory domains.

Conclusions

Similar connectivity patterns have previously been observed in the PCC and ACC in resting and visual processing data [7,8]; however, the present data illustrate that these connectivity patterns are disrupted during more cognitively demanding tasks. The high degree of overlap observed between the connectivity map of PCC activations and deactivations confirms previous evidence that the PCC plays a critical role in the default mode network [2,7].

References

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