Investigating the deactivation of default mode network across multiple cognitive task

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Introduction

Recently the task independent deactivation (TID) properties of the default mode network (DMN) have attracted increased attention in the neuroscience community because of their potential functional interpretations [1-6]. TID refers to a decrease in brain activity during an active task relative to a baseline. However, most deactivation studies have used one or only a few cognitive tasks in the same subjects, which makes difficult the study TID features. In this study a series of different cognitive systems (language, memory, emotion, mathematics and mental rotation) were tested in a group of subjects to investigate the TID characteristics in DMN, specifically in terms of spatial differences across the various tasks.

Methods

Stimuli and image acquisitions: Five subjects participated in the scans (mean age, 23.4 years). Five tasks were chosen to test different 'high cognitive systems': math, working memory, emotion discrimination, mental rotation and lexical. Tasks were calibrated to have similar difficulty (85% accuracy) prior to the fMRI scans across the group of subjects. A block design was used (typical task duration 18s). Three fMRI runs were acquired for each subject. In each run tasks were randomly alternated with 20s fixation periods, each task being repeated 4 times for a total of 20 task blocks. Functional EPI images were acquired using a 4.0 T Bruker Medspec scanner equipped with an eight-channel multi receive system, TR/TE = 2000/33 ms, flip angle=73[0], 3x3x3 mm^3. Structural images were acquired with an optimized 3D MPRAGE sequence (1x1x1 mm^3, GRAPPA IPAT = 2) [7].fMRI data Analysis: Data were analyzed using FSL (www.fmrib.ox.ac.uk/fsl/). Preprocessing of functional scans included brain extraction, motion correction, high-pass temporal filtering of 100 sec, spatial smoothing (Gaussian, 6mm FWHM) and normalization to the standard MNI space. After preprocessing, statistical analyses were performed at the single-subject level by using the general linear model. Each block was modeled with gamma hemodynamic response function (HRF) along with temporal derivative, and then group-level analysis was carried out using FLAME (FMRIB's Local Analysis of Mixed Effects). A cluster-based correction of the Z-statistic images was performed. Result Z statistic images were thresholded using an initial clusters determined by Z > 2.3 and a corrected cluster significance threshold of p<0.05.

Results and discussion

Fig. 1 shows the group deactivation maps in the five tasks. Deactivation areas include posterior cingular cortex, precuneous, medial prefrontal cortex (MPFC), anterior cingular cortex, angular gyrus, insula, middle temporal gyrus, superior frontal gyrus. Fig. 2 shows how primary deactivated regions in similar tasks from previous studies [2-6] (top row) are comparable to those found in our study (bottom row). In particular, the MPFC showed significant deactivation in all tasks, in agreement with previous studies reporting its role in task switching and self-referential processing [4].In Fig. 1, subjects showed significant deactivation in the posterior insula (BA 13) during math and mental rotation task. But insula deactivation region were not found during the emotion, lexical and memory tasks. The overlapping deactivation in the five tasks gives most of the DMN. Although some deactivation regions vary consistently across different tasks, including insula, PCC, angular gyrus and subregion of MPFC. These results suggest that different subregions of DMN mediate different cogtive tasks. This task-dependent variability in the deactivation network supports the idea that deactivate areas reflect resource reallocation in the DMN caused by the task. One potential source of variability that needs to be further investigated relates to the effects of subject-specific cerebral blood flow variations and their effects across different cognitive tasks [8].

References: [1] Raichle et al., PNAS,98:676–682, 2001. [2] McKiernan et al., J Cogn Neurosci,15:394-408, 2003. [3] Greicus MD et al., PNAS, 100: 253-8, 2003. [4] Fox et al. PNAS, 102:9673–9678, 2005. [5] Binder et al., J. Cogn. Neurosci,11:80-95,1999. [6] Mazoyer et al., Brain Res.Bull, 54:287–298, 2001. [7] Papinutto N et al., ESMRMB, 2008. [8] Tomasi D et al., HBM, 27(8): 694 – 705, 2006.
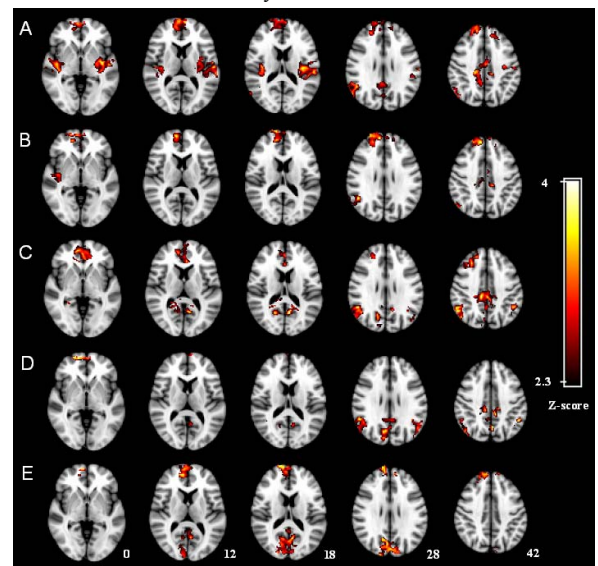
Fig. 1 Group DMN deactivation in five different cognitive tasks: (A) Math, (B) Rotation, (C) Emotion, (D) Lexical and (E) Working memory (Z>2.3, p<0.05).
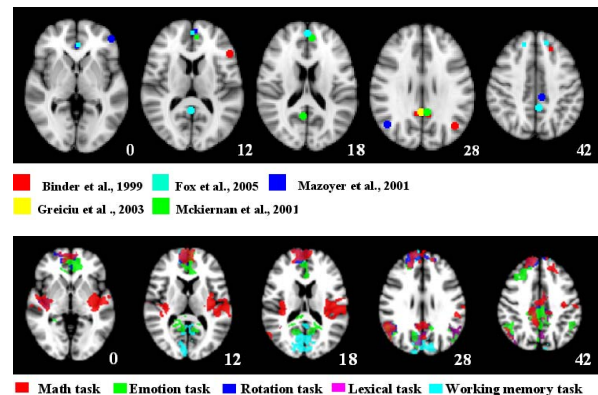

Fig. 2 Top row: Deactivation findings reported in the literature in similar tasks. Bottom row: Overlapping deactivations given by the five tasks in this study.