TASK-INDUCED DEACTIVATION IN MEDIAL STRUCTURES OF THE DEFAULT MODE NETWORK VARIED ACCORDING TO TASK TYPES

Kayako Matsuo[1], Katsuaki Suzuki[1], Keisuke Wakusawa[2], Kiyokazu Takebayashi[1], Yasuo Takehara[3], and Norio Mori[1]

[1]*Department of Psychiatry, Hamamatsu University School of Medicine, Hamamatsu, Shizuoka, Japan,* [2]*Research Center for Child Mental Development, Hamamatsu University School of Medicine, Hamamatsu, Shizuoka, Japan,* [3]*Department of Radiology, Hamamatsu University School of Medicine, Hamamatsu, Shizuoka, Japan*

Target audience: researchers of the DMN and task-induced deactivation during fMRI.

Purpose: Task-induced deactivation (TID), which refers to signal decreases during task periods computed by "contrast greater than task blocks" in task-employed fMRI, often delineates the default mode network (DMN) [1], and has revealed relevance to the levels of cognitive impairments such as in schizophrenia [2]. However, task characteristics to induce the deactivation have not been sufficiently investigated. A study showed that cognitive demands and task specificity altered the deactivation in the DMN [3], whereas another showed no changes by task difficulty [4]. Thus, we examined the TID using 4 different task conditions that varied types and demands for cognitive processing. Medial structures of the DMN, i.e., the posterior cingulate cortex (PCC), precuneus (PREC) and medial prefrontal cortex (mPFC) were specifically focused as "core" DMN regions.

Methods: Ten right-handed controls were studied after obtaining written informed consent. The protocol was approved by the institutional review board in adherence to the Declaration of Helsinki. Scanning was performed using a 3T MR scanner with a 32-channel phased array coil (Discovery MR750 3.0T, GE Healthcare). A GRE-EPI sequence was employed for fMRI using the following parameters: TR/TE = 2000 ms/22 ms, flip angle = 90 deg, 45 slices, 3 mm thick with no gap interleaved, FOV 192 mm, matrix size 64 x 64 and 136 volumes per run (4 min 32 sec). Each subject performed 4 runs that corresponded to the following 4 task conditions in a block design (Fig. 1). (1) Checkerboard: subjects passively viewed a plus mark in the middle of white-and-black checkerboard flickering (4 Hz). (2) Visuomotor: subjects clasped and unclasped their left hand in tune with a presentation of clasped and unclasped hands (0.5 Hz). (3) Counting: subjects covertly counted numbers by their own pace during the task blocks; they started the counting from 1 for every task block and reported the maximum number counted after the run. (4) All 3 tasks: all the above tasks (i.e., checkerboard, visuomotor and counting) were simultaneously performed in a task block. SPM12 (http://www.fil.ion.ucl.ac.uk/spm/) was used for image analyses. After preprocessing, all 4 runs were included in a design matrix to compute contrast estimates of 4 conditions individually. The contrast estimates (corresponding to the effects of task>contrast blocks) were then introduced into a random-effects model to conduct group statistics and compute task-induced activation (TIA) and task-induced deactivation (TID) for each condition.

Results and discussion: We obtained reasonable TIA maps that corresponded to our task conditions (Fig. 2). We found that the checkerboard only minimally deactivate the mPFC as compared to other task conditions (Figs. 3 and 4). Not only a smaller range of the TID (Fig. 3) but also the smaller signal decrease (Fig. 4) in the mPFC were observed during the checkerboard. The results might reflect a lower cognitive demand during the checkerboard because subjects just passively viewed the flickering in the condition; other conditions required more active processing. In contrast, the deactivated area and the signal decrease during the checkerboard were enhanced in the PCC/PREC (Figs. 3 and 4). On the other hand, conditions including the hand action (visuomotor and "all 3 tasks") showed less deactivation in the area anteriorly adjacent to the parieto-occipital sulcus (Fig. 3, magenta line). Thus, the hand action during the task period decreased the TID in the region that is typically used as a "seed" region of the PCC in the functional connectivity analysis of resting-state fMRI. The finding indicated that care should be taken when we design task paradigms and interpret the results in the investigation with the TID. Additionally, we found that the area posteriorly adjacent to the parieto-occipital sulcus, i.e., upper part of the cuneus, was deactivated during conditions including extensive visual processing (Fig. 3, upper 2 panels of checkerboard and visuomotor). Interestingly, the counting appeared to decrease the TID in the upper cuneus because the condition "all 3 tasks" also included the visuomotor (as well as the counting) but showed minimal TID (Figs. 3 and 4, lower right panels).

Conclusions: The deactivation in the medial structures of the DMN demonstrated varieties associated with performances during task blocks. Demands for cognitive processing affected the mPFC, whereas task types modulated regions in the PCC/PREC as well as upper part of the cuneus. Specifically, the hand action decreased the TID in the PCC/PREC area adjacent to the parieto-occipital sulcus. The findings provide important information for the designing of task paradigms and the interpretation in the examination of cognitive impairments using the TID.

References:

[1] Anticevic et al., Trends Cogn Sci. 2012, 16(12):584-592. [2] Schneider et al., Schizophr Res, 2011, 125(2-3):110-117. [3] Mayer et al., Hum Brain Mapp. 2010, 31(1):126-139. [4] Gilbert et al., Front Psychol, 2012, 3:125.

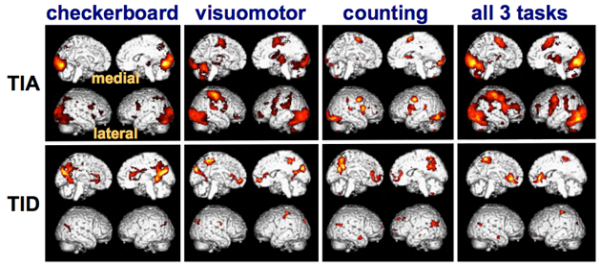

Fig. 2. 3D rendering of task-induced activation (TIA) and task-induced deactivation (TID). N=10. P<0.005, uncorrected and k=20. In each of TIA and TID, the upper panels show a medial view, whereas the lower panels show a lateral view of the hemispheres. The TIA reflects the signal increases in task>contrast blocks, whereas the TID reflects those in contrast>task blocks.

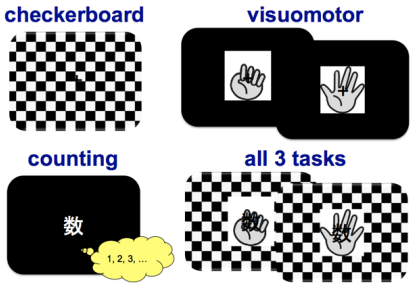

Fig. 1. Four task conditions employed. Each condition was executed in a separate run by a block design. Contrast blocks showed a plus mark. One block lasted 16 sec. Nine contrast blocks and eight task blocks alternately presented. The character in the counting condition indicates "number".

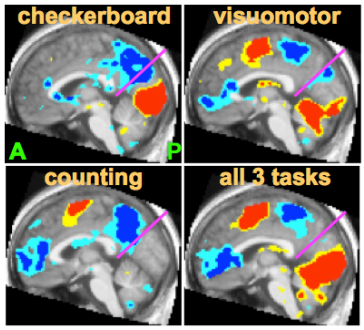

Fig. 3. Medial wall rendering at x=-2 (MNI). N=10. Red (p<0.005) and yellow (p<0.05) indicate task-induced activation (TIA), whereas blue (p<0.005) and cyan (p<0.05) indicate task-induced deactivation (TID) (all uncorrected). Magenta lines indicate rough locations of the parieto-occipital sulcus. A, anterior; P, posterior. The background sagittal section shows the average of T1-weighted images of all subjects.

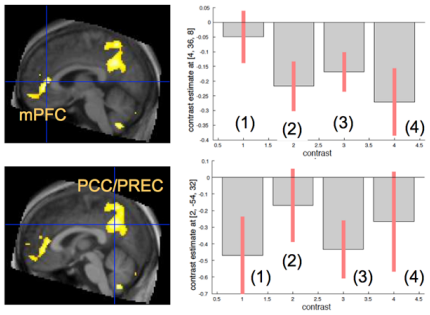

Fig. 4. Contrast estimates of peak coordinates in the mPFC and PCC/PREC. N=10. P<0.005, uncorrected and k=20. The left panels show maps by task-induced deactivation (TID) during the counting condition. Contrast estimates of each condition at the locations indicated by the blue crosshairs in the left panels were shown in the right panels. (1) Checkerboard, (2) visuomotor, (3) counting and (4) all 3 tasks. All conditions demonstrate a signal decrease during the task blocks (i.e., TID) as negative values of the contrast estimates.