FUNCTIONAL CONNECTIVITY IN TASK SWITCHING PARADIGM

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Introduction: An ability to set mental goals and follow certain "rules" is necessary for activities of daily living, such as driving a car, cooking meals, or using a computer. Various activities of daily living and situations also require people to switch from one task to another. However, situations that require individuals to perform a series of parallel tasks reduce accuracy and processing speed. Thus, constructing suitable mental rules and goals, while inhibiting inappropriate ones, and switching between them involves certain "costs." The Task-Switching Paradigm (TSP) is one method of measuring such mental costs (Cepeda, Kramer, & Sather, 2001; Hsieh & Liu, 2005; Kramer et al., 1999). In general, it has been considered that blood oxygenation level dependency (BOLD) signals change in a task load-dependent manner and are also affected by aging (Gutchess et al., 2007; Townsend, Adamo & Haist, 2006). However, the interaction between task load and aging in the regions responsible for the TSP remains unclear. The task load-dependent BOLD response gradient during the TSP might be a useful indicator of the physiological effects of aging on task-set reconfiguration and inhibitive function. This study attempted to demonstrate the extent of the task load-dependent augmentation of brain activation and the change of functional connectivity in young adults during the TSP prior to an aging study.

Material and Methods: Twenty healthy young adults (mean age: 22.80 ±3.44, 9 males) participated in the study. The divalent TSP was designed for fMRI. In switching condition, the participants were required to assess the stimuli based on their color (if they were presented in the top row) or shape (if they were presented in the bottom row). The nonswitching condition (only the shape judgment) was performed to remove simple responses to stimuli and highlight the task-set reconfiguration and interference effects. Three task speed conditions were employed; i.e., the ISI was altered to produce high (HS, 50ms), medium (MS, 650ms), and low speed (LS, 1250ms) conditions. Both conditions consisted of 9 task (HS×3, MS ×3, LS ×3) and 10 rest blocks, and each task blocks consisted of 20 trials. Functional data were obtained using a T2* weighted gradient recalled echo EPI sequence (TR = 3000 ms, TE = 30 ms, 39 axial slices, 3 mm thick, FOV = 19.2 cm) on a 3T MRI scanner. The functional images were realigned, normalized and analyzed by SPM8. For each subject, the task block was subtracted from the fixation rest block (1st level analysis), and the switching vs. nonswitching contrasts were submitted to subsequent group-level analysis (2nd level analysis). To examine task load-depended differences of brain network responsible for TSP, we utilized structural equation modeling (SEM) to compare the functional connectivity among the three task speed conditions. After a conjunction analysis, ROIs for SEM were restricted to the bilateral dorsolateral prefrontal cortex (DLPFC), intraparietal sulcus (IPC), anterior insular cortex, and pre-supplementary motor area (pre-SMA).

Results: The significant switching vs. nonswitching activation was observed in the premotor and supplemental motor area (SMA, [BA] 6), the DLPFC including the inferior and the middle frontal gyri (IFG, MFG, [BA] 8, 9, 45, 46, 47), the anterior cingulate cortex (ACC, [BA] 24), the posterior cingulate cortex (PCC, [BA] 23, 31), the anterior insular cortex ([BA] 13), the superior parietal lobule (SPL [BA] 7) and the inferior parietal lobule (IPL, [BA] 39, 40) including IPC of each hemisphere under all conditions (p < 0.05, FWE, RFX). The activation of these regions was augmented as task load increased. The significant activation (left) and path model illustration for the three conditions (right) are graphically represented in Figure 1. The three models were confirmed to have a good fit with each condition of the current data; i.e., LS (χ^2 = 8.48, p = 0.58, *ns*., GFI = 0.90, RMSEA =0.00), MS (χ^2 = 10.72, p = 0.64, *ns*., GFI = 0.87, RMSEA =0.00), HS (χ^2 = 11.08, p = 0.68, *ns*., GFI = 0.87, RMSEA =0.00).These results showed that the activation of these regions was augmented and their connectivity was extended as task load increased.

Conclusion: TSP demonstrated the activation in the frontal and parietal region. The DLPFC were involved in the selection of representations for upcoming actions (Egner & Hirsch, 2005; Rowe et al., 2005), the maintenance of visual attention (Curtis & D'Esposito, 2003), and memory rehearsal (Smith & Jonides, 1999; Vallar et al., 1997). Although they are difficult to separate from the frontal regions, the posterior parietal regions, including the IPC, SPL and IPL, might be responsible for the short-term storage of visuospatial information (Todd & Marois, 2004) and orienting visual attention (Hopfinger, 2000). It was suggested that the SMA was responsible for coordinating temporal sequences of actions (Lee & Quessy, 2003; Picard & Strick, 2003). Furthermore, previous study has been reported that the pre-SMA and the anterior insular cortex activate during attention and working memory task (Petit et al., 1998; Sörös et al., 2007). These regions were activated in all conditions in this study, and they were augmented as task load increased. The result of SEM showed that functional connectivity of these regions was extended depending on task load, though that network was fragmentary in low load. It was considered that network of these regions worked as a central executive, and it controlled switching of attention, task-set reconfiguration and inhibition during TSP. The comparison of task load-dependent BOLD response gradient and functional connectivity using divalent TSP for fMRI between young and alder adults might be useful for detecting the effects of aging on executive function in the clinical setting.

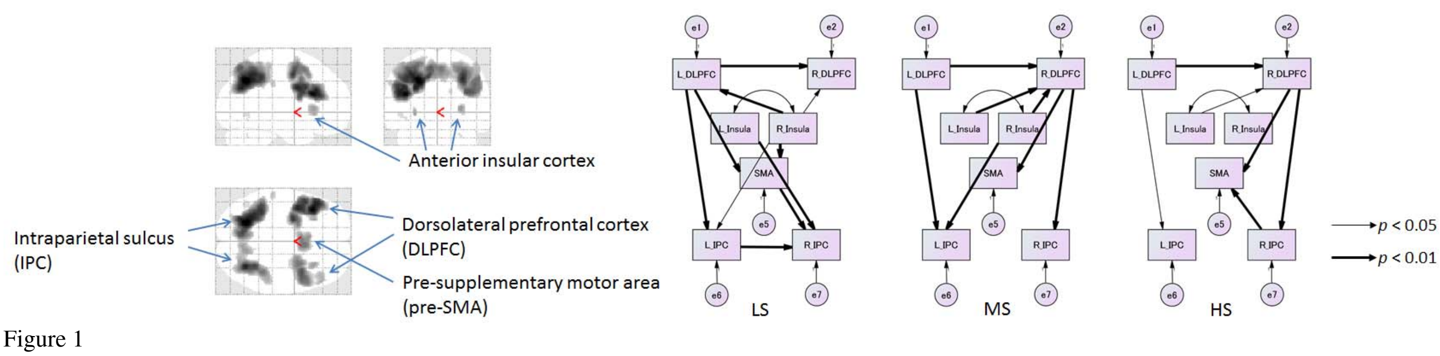

Figure 1
The brain regions that exhibited the greatest activation in all conditions in conjunction analysis (left) and path model illustration for the three conditions with different speed (right).