Age-related effects in brain activation with working memory tasks: An fMRI study

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Introduction

Working memory can be seen as a mental buffer for temporal information retrieval from long-term memory, temporal storage of new information, and manipulation of this information in service of ongoing mental tasks [1]. A decline in working memory is well documented with increasing age [2]. However, no investigation has directly examined neural correlates associated with working memory decline in wide distribution of age. Therefore, the aim of this study was to elucidate the neuro-cognitive processes underlying age-related differences in working memory using fMRI. In addition, we also investigated the age-related differences in deactivated brain network during working memory task.

Subjects and methods

The data from 68 right handed subjects aged 18 to 70 years old were included in this study. All participants gave their written informed consent. Functional magnetic resonance imaging was employed to assess cortical activities during the performance of 0-back and 2-back working memory paradigm using Korean alphabet as mnemonic content. In the 0-back condition, participants were asked to remember a target letter that was presented at the beginning of each trial block. In the 2-back condition, they were asked to respond when a letter matched one that had been presented two letters before the present letter. BOLD functional images were acquired using a 3.0T GE HD scanner (EPI, TR=3000ms, TE=40ms, matrix=64x64, Thickness=4.0mm, FOV=220mm, no gap). Anatomical images were acquired using 3D-FSPGR sequence (TR=7.8ms, TE=3ms, matrix=256x256, no gap). Image processing and statistical analyses were carried out using MATLAB and SPM8. In fMRI data within-group analysis, contrast images from the analysis of individual subjects were analyzed by one-sample *t*-test, thereby generating a random-effects model, allowing inference to the general population. The SPM{t}s were thresholded at $P<0.05$, false discovery rate (FDR) corrected for multiple comparisons across the whole brain. Furthermore, we mapped voxel-wise correlations between each subject's age and brain activation during 2-back memory task. Correlations were considered significant at $p<0.05$ FDR-corrected for the volume of activated regions. Pearson correlation analyses were used to determine the correlations between mean percentage changes in BOLD signal in the brain regions, which showed like working memory networks (WMN) and default mode networks (DMN) and each subject's age. All statistical analyses were performed using SPSS software. Statistical significance was defined at $p<0.05$.

Results and Discussion

Age distribution and the performance data of the task are presented in Figure 1. Within-group analysis showed activity in the network of the frontal and parietal cortical areas for the 2-back working memory task (Fig. 2). The network included activation in the ventrolateral prefrontal cortex (VLPFC), inferior temporal cortex (ITC), dorsolateral prefrontal cortex (DLPFC), dorsal medial prefrontal cortex (mPFC), and the inferior and superior parietal cortices. And the within-group analysis showed deactivated brain regions in which BOLD activity was less in the 2-back task than in the 0-back task. The deactivation network included the middle and superior temporal poles, amygdale, hippocampus, insula, posterior cingulate cortex (PCC), medial parietal cortex, and sensorimotor cortex. The multiple regression analysis with aging showed that 2-back working memory activation network (WMN) was anti-correlated with age, whereas 2-back deactivation network (DMN) was correlated with age (Fig. 3,4). Our finding suggest that decreased brain activity of WMN has interpreted as a reflection of cognitive deficits with increasing age and increased activity of DMN has interpreted as compensatory.

References

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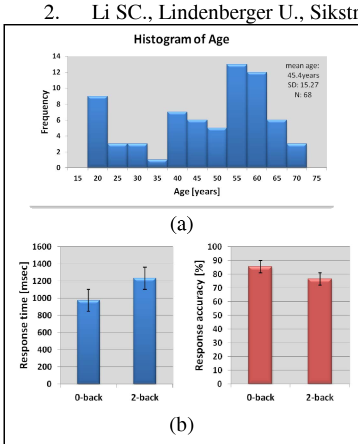

Fig 1. Histogram of age (a) and mean n-back working memory task performance in all subjects.

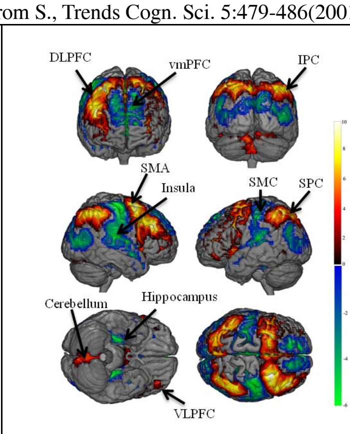

Fig 2. Brain activations during the 2-back memory task in all subjects. Statistical parametric maps of brain regions (one-sample *t*-test) showing significant activation (yellow) and deactivation (green) at a statistical threshold of p<0.05 (FDR-corrected).

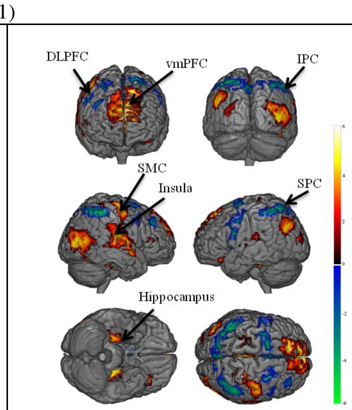

Fig 3. Correlation map between age and brain activations during the 2-back memory task in all subjects. Statistical parametric maps of brain regions (multiple regression test) showing significant correlation (yellow) and anti-correlation (green) with age at a statistical threshold of p<0.05 (FDR-corrected).

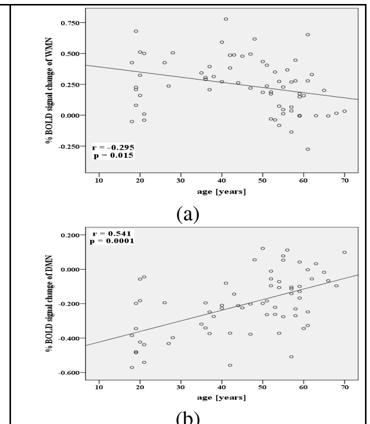

Fig 4. Correlation between BOLD signal change and age. Mean percentage BOLD signal change in the WMN (a) showed negative correlation with age, while signal change in the DMN (b) showed positive correlation with age.