An fMRI Study of Age Effects on Frontal-Striatal Neural Circuit Functions

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Introduction

Behavioral and brain imaging data indicate clear aging-related changes in the frontal-striatal neural circuit, a brain system that is thought to be associated with attention and executive function (1). Some possible regions associated with this circuit are middle frontal gyrus (MFG), inferior frontal gyrus (IFG), superior frontal gyrus (SFG), superior and inferior parietal lobules (SPL and IPL), and anterior cingulate cortex (ACC) (2). To investigate the modification of this circuit with aging, we compared younger and older adult participants in an fMRI study using a flanker task paradigm that was designed to investigate group differences in attention and executive functions. This study found that various anatomical regions associated this circuit were modified with aging as reflected by either the amplitude or latency of the BOLD response.

Methods

Twenty-two young adults (11 males, age 20 ± 3 yrs) and twenty-two older adults (9 males, age 74 ± 6 yrs) participated in this study. A flanker paradigm with a rapid event-related design included 128 trials for each of the three conditions: Congruent (">>>>>>>" or "<<<<<<<"), Incongruent (">>><>>>" or "<<<><<<") and Neutral ("□□□>□□□" or "□□□<□□□"). This paradigm included four 7-minute runs. Each run included 32 trials for each condition randomly alternated with a fixation cross. Each stimulus array was presented for 2.5 sec, during which time the participant pressed a button to identify the direction of the central arrow head. Following a 10-second baseline fixation cross, the stimulus trials were randomized to optimize the calculation of the hemodynamic response function for each stimulus condition and the contrasts between them. The stimuli for all trials and the fixation cross were in white and were presented on a black background. For each stimulus condition, flankers were presented in the opposite directions an equal number of times.

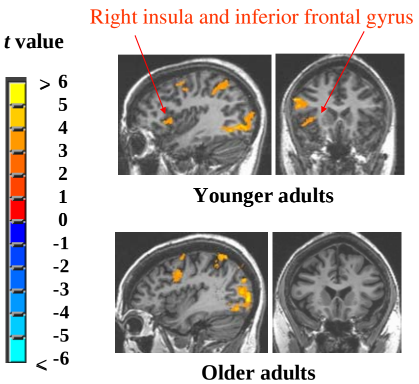

Figure 1. The differential activation of Incongruent vs. Congruent is shown based on the ANOVA analysis of the young or older groups (voxel based $p \leq 0.005$ and whole brain corrected $p \leq 0.021$).

The fMRI data were acquired on a 3T GE Signa EXCITE scanner (GE Healthcare, Waukesha, WI) with an 8-channel head coil. Echo planar images, starting from the most inferior regions of the brain, were acquired with the following parameters: 34 contiguous 3-mm axial slices in an interleaved order, TE = 27.7 ms, TR = 2500 ms, flip angle = 80°, FOV = 22 cm, matrix size = 64 × 64, ramp sampling, and with the first four data points discarded. Each volume of slices was acquired 164 times during each of the four functional runs while a subject viewed the stimuli and pressed a button to indicate the pointing direction of the central arrow, resulting in a total of 656 volumes of images over the course of the entire experiment.

All fMRI data pre-processing and analyses were conducted with AFNI software (3). 3dDeconvolve software was applied for multiple linear regressions to deconvolve the impulse response function (IRF) with respect to each trial type (4). After the percent signal change was estimated with respect to each condition for each subject, an ANOVA was performed on the data sets for group analysis with a mixed-effect two-factor model for each group. Then another ANOVA was performed to compare the young and older groups to assess the difference between these two groups directly for each condition with a mixed-effect three-factor model.

Results and Discussion

Pair-wise differential activations are shown in the whole-brain within and between group analyses (Figures 1 & 2). A region at the right insula and right IFG, both of which are associated with the attention and executive function (2), was shown to be more active for the Incongruent condition than the Congruent condition for the younger group, but this differential activation was not found in the older group at the corresponding region (Figure 1). This result is consistent with the behavioral data, that the response time difference between Incongruent and Congruent conditions was longer for older than younger adults. This result suggests the reduced activation at the right insula and the right IFG with aging. The direct statistical comparison between the young and older adults on the difference of BOLD percent signal change between the Incongruent and Congruent conditions indicated that the older adults were more active in the left SFG and MFG than the younger adults when resolving the conflict (Figure 2). This suggests compensation in other brain regions during task resolution with aging. On the other hand, this comparison showed that the younger adults were more active at the inferior part of the ACC than older adults. Age group comparisons of the hemodynamic response latency based on the time to peak showed that the left MFG/cingulate gyrus responded earlier to Incongruent stimuli for young adults than the older adults (voxel based $p \leq 0.005$, whole brain corrected $p \leq 0.021$), but no significant difference between the two groups was found at this region with respect to the Congruent stimuli. This delayed response is consistent with the slower differential behavior responses in older adults, and also suggests that the frontal-striatal circuit is modified with aging.

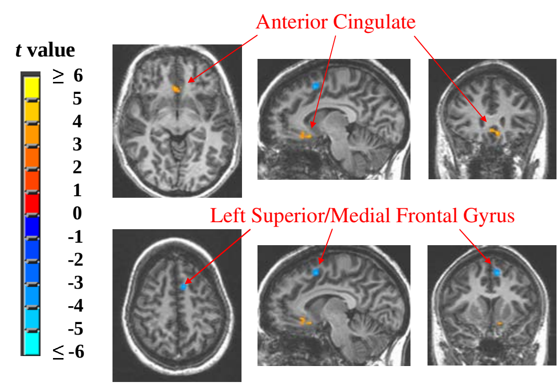

Figure 2. ANOVA analysis between the young and older populations on the difference of BOLD percent signal change between Incongruent and Congruent conditions (voxel based $p \leqslant 0.005$ and whole brain corrected $p \leqslant 0.021$).

References

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