Developmental fMRI Patterns Associated with Visuospatial Working Memory and Response Inhibition

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Introduction: Inhibitory and working memory processes are thought to contribute to the development of other cognitive abilities, including learning, perception, motor activity, and emotion[1]. fMRI studies have demonstrated brain regions activated during response inhibition tasks, including the dorsolateral and ventrolateral prefrontal cortex, and the anterior cingulate[2,3]. Neurodevelopmental investigations of working memory/response inhibition in typically maturing children and adolescents to date have focused on prefrontal activation patterns. From a neural systems perspective, we suspected that significant developmental plasticity would also be evident in the parietal-occipital regions interconnected with prefrontal cortex, and that the role of the prefrontal cortex would decrease as the executive resources needed for go no–go performance by older children would decrease. For the present study, we employed a go no-go task during fMRI imaging in order to investigate age-related plasticity in the neural bases of response inhibition and working memory capacities in typically developing children and adolescents. We hypothesized that a network of structures including the superior parietal and occipital cortical regions would become more active with age in contrast to broader prefrontal, anterior cingulate, parietal, and insula regions that would become less active with age, as maturing participants would need fewer executive resources to manage the working memory and inhibitory demands of the go no-go task.

Methods:

Human Subjects: Sixteen normal healthy children and adolescents (8-19 years of age) were studied. All subjects and parents of the subjects under 18 years old gave informed written consent prior to participation. Out-of-magnet cognitive tests showed average to above average levels of general intellect, math, reading, and attentional abilities for the sample.

Cognitive fMRI Task: During fMRI scanning on a Philips 3T magnet, participants completed a Go No-go task viewed through LCD goggles. The paradigm included alternating baseline (All Go, 84 s) and experimental (Go No-go, 168 s) trials 3 times (see Figure 1 for examples). Responses were recorded through a 2-button (left, right) handheld device. A series of T_2*-weighted EPI images (TR / TE / FA = 3000 ms / 35 ms / 90º, 25 5-cm-thick axial slices with no gap between slices, FOV = 23 × 23 cm^2, matrix = 80 × 80, 203 repetitions) were obtained for functional data acquisition.

Data processing and analysis : Images were processed using SPM2 software. Brain activations associated with the All Go (baseline) task were subtracted from the experimental Go No-go task, isolating cognitive processes of response inhibition/working memory. Average activation maps and regression analysis of negative and positive age effects were computed.

Results: Average activation maps for the developmental sample identified a network of structures associated with the go no-go experimental task, including the right ventrolateral, dorsolateral, and superior prefrontal regions, the left anterior cingulate, bilateral hippocampus, and bilateral insula. Age regression analyses indicated areas of positive (increasing) and negative (decreasing) correlation. Significant increasing activations with age were localized to the left and right occipital cortices, right frontal superior region, superior parietal cortex bilaterally, left occipito-temporal junction, right lateral temporal lobe, right posterior cingulate, and left basal ganglia. Areas correlated negatively with developmental age reflected extensive neurodevelopmental changes, with the largest volumes of change involving the dorsolateral prefrontal bilaterally, left inferior parietal, mid frontal superior medial, anterior cingulate bilaterally, and left anterior insula. These dynamic changes are summarized in the 3D rendered Figure 2.

Discussion: Results identified significant neurodevelopmental changes in structural activation patterns during a go no-go task. Age regression analyses showed significant age related differences in multiple structures beyond the prefrontal cortex, including the occipital, parietal, cingulate, and basal ganglia regions. There were particularly marked decrements in age-related activation in the prefrontal, inferior parietal, cingulate and insula regions, suggesting that neural processes subserving inhibitory control and working memory became more focal in adolescence in comparison to widespread areas of activation at younger ages.

References:

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A B

Figure 1. Examples of baseline All Go (A) and experimental Go Nogo (B) problems.

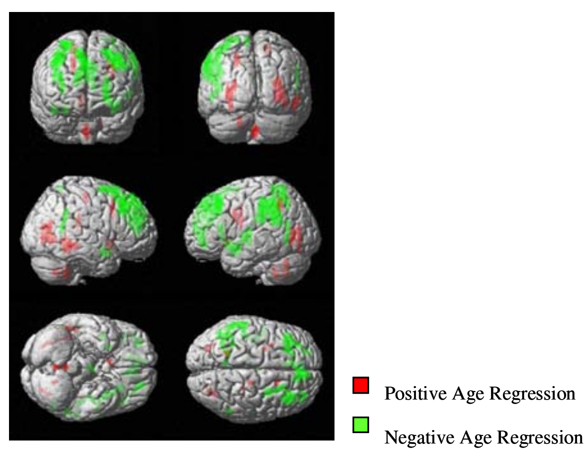

Figure 2. Summary 3-D rendering of anatomical regions showing significant positive correlations (in red) and significant negative correlations (in green) with developmental age during the go nogo task (p < .01, v = 10).