Hyperactive and Inattentive Symptoms are Correlated with Prefrontal and Parietal Activity during Stroop Task in Adults with ADHD

Gregory C. Burgess1, Blaine J. Amers,2 Brendan E. Depue1, Erik G. Willcutt1,2, & Marie T. Banich1,3

1University of Colorado, Boulder; 2Dept. of Psychology, 3Institute for Behavioral Genetics,
1Institute of Cognitive Science; 2University of Colorado Denver-Health Sciences, Dept. of Psychiatry

Introduction
- Individuals with Attention Deficit Hyperactivity Disorder (ADHD) are reported to have dysfunction in brain regions implicated in executive control processes (Bush, Valera, & Rapol, 2005)
- The Stroop Task requires the engagement of executive control processes to handle competition and conflict between sources of color-related information
- During the Stroop Task, we found atypical activation in adults with ADHD combined subtype in 1) prefrontal regions implicated in providing top-down biasing toward task-relevant features and selecting specific task-relevant representations (Milham, Banich, & Barad, 2003), and 2) in regions involved in the evaluation of responses.

We hypothesized that:
1. The severity of inattention and hyperactivity symptoms in ADHD may relate to activation in executive control regions.
2. Hyperactivity and inattentive symptoms may show different relationships to activity in executive control regions.

Method
Participants
- 17 college-aged adults (6 female), meeting DSM-IV criteria for ADHD combined subtype
- Diagnosed through structured interview assessing self- and parent-reports of current and childhood symptoms
- Participants also reported the prevalence of each symptom on a scale from 0 (never / none at all) to 3 (always / often)
- Correlations with behavior and BOLD activation were computed on these scores.
- Hyperactive & inattentive symptom ratings were correlated (r = 0.614, p = 0.004)

FMRI Acquisition / Analysis
Acquisition: GE 3 Tesla magnet: BOLD gradient-echo, T2^2 weighted EPI; TR=2000 ms; 64 x 64 matrix, 29 slices, 4 mm slice thickness, 0 mm slice gap along AC-PC line, flip angle 90°
Analysis: Standard FSL pre-processing: computed correlations between activity and ADHD symptomatology using FEAT
SPMs thresholded at Z = 2.81, p < .005

Design
- Color-word Stroop task (Figure 1)
  - Event-related / blocked design
  - 4 blocks: congruent (C), neutral (N), incongruent (I), fixation (F)
  - All blocks consisted of 50% frequent neutral trials (e.g., sum) and 50% trials corresponding to the block (e.g., red, I, blue)
  - 12 trials per block, 11 blocks per run (e.g., FCINNCCIF), 3 runs

Imaging Results
1. Hyperactive Symptoms
A. Blocked Analyses: 1. Competition regressor (I+C > N): 2 sources of color information vs. 1 source
   - Associations driven by increased activity during the N block.

2. Inattentive Symptoms
B. Blocked Analyses: Competition regressor (I+C > N):
   - Associations driven by decreased activity in I & C blocks.

Imaging Results (cont.)
2. Inattentive Symptoms: Block-Related Analyses
   - Association driven by decreased activity in I & C blocks.

Behavioral Results
Table 2: Correlations with behavioral performance

Behavioral Results

Conclusions
- Even though hyperactive and inattentive symptoms were not significantly correlated in this sample, their relationships with brain activity appear to dissociate.

Hyperactivity Symptoms
1a. As hyperactivity increases, activity in executive control regions increases for neutral, but not for incongruent or neutral blocks.
1b. We suggest that hyperactivity reflects insufficient top-down bias from executive control regions toward task-relevant processing.
2a. The more hyperactive an individual, the more transient responses to incongruent trials, and less transient responses to neutral trials.
2b. This pattern is suggestive of increased reliance on reactive control mechanisms (Braver, Gray, & Burgess, in press) to deal with attentional demands, as a consequence of their inability to impose the correct top-down bias.

Inattentive Symptoms
1a. As inattention increases, activity in executive control regions decreases for neutral, but not for incongruent or neutral blocks.
1b. We suggest that inattention may arise from insufficient maintenance of executive control processes under difficult distracting conditions.
2a. The more inattentive an individual, the less transient responses to incongruent trials.
2b. These findings suggest that inattention may also indicate an inability to engage reactive control mechanisms in the face of attentional demands.