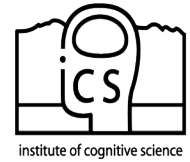




Hyperactive and Inattentive Symptoms are Correlated with Prefrontal and Parietal Activity during Stroop Task in Adults with ADHD

Gregory C. Burgess¹, Blaine J. Ames¹, Brendan E. Depue¹, Erik G. Willcutt^{1,2}, & Marie T. Banich^{1,3,4}
 University of Colorado, Boulder: ¹Dept. of Psychology, ²Institute for Behavioral Genetics, ³Institute of Cognitive Science, ⁴University 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, & Seidman, 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 (See Poster 122 M-PM) 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:

- The severity of inattention and hyperactivity symptoms in ADHD may relate to activation in executive control regions.
- Hyperactivity and inattentive symptoms may show different relationships to activity in executive control regions

Methods

Participants.

- 17 college-aged adults (6 female), meeting DSM-IV criteria for ADHD combined subtype
- Diagnosed via structured interview assessing self- and parent-reports of current & childhood symptoms

Table 1: Number of symptoms endorsed (out of 9)

	Self-report ratings			Parent ratings		
	age	inatt.	hyper.	inatt.	hyper.	total
mean	19.89	6.88	5.94	5.73	2.72	
sd	1.59	1.78	2.07	2.56	1.76	

- 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*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°

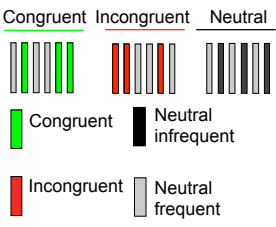
Analysis: Standard FSL pre-processing; computed correlations between activity and ADHD symptomatology using FEAT.

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, lot, blue**)
- 12 trials per block, 11 blocks per run (e.g., FCINNCCNIF), 3 runs.

Figure 1: Experimental Design



1. Blocked Analyses:

- Two regressors were of interest: -Competition between sources of color information (i. e., color information in both the word and ink color) vs. color information only in ink color): I>N & C>N
- Conflict between sources of color information vs. no conflict: I > C



2. Event-Related Analyses:

- We compared event-related activity for individual trial types within-blocks

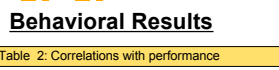
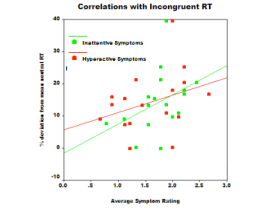


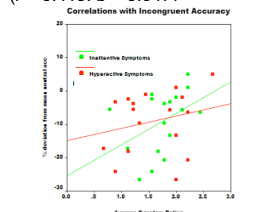
Table 2: Correlations with performance

	accuracy		RT	
	cong.	incong.	cong.	incong.
hyper.	-0.024	0.232	0.249	0.332
inatt.	-0.120	0.419	0.225	0.398

- Incongruent reaction time takes longer as *inattentive* symptoms increase ($r = 0.398, p = 0.057$)



- Incongruent accuracy increases as *inattentive* symptoms increase ($r = 0.419, p = 0.047$)



- These results suggest that, as *inattention* increases, participants trade speed for accuracy

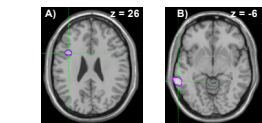
Imaging Results

- Negative association of regressor with symptom severity
- Positive association of regressor with symptom severity

1. Hyperactive Symptoms:

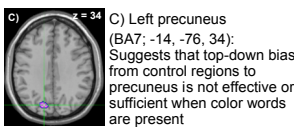
A. Blocked Analyses:

- I. Competition regressor (I+C > N)
2 sources of color information vs. 1 source
Associations driven by increased activity during the N block.



- A) L. middle frontal gyrus (BA 9; -38, 10, 26): Suggests that greater top-down bias toward ink color information is needed, even when competition is absent
- B) L. middle temporal gyrus (BA21; -64, -42, -6): Suggests increased language-related processing (reading) during N block

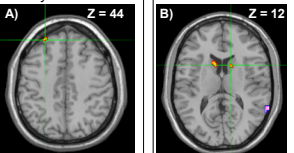
Association driven by decreased activity during I & C blocks



- C) Left precuneus (BA7; -14, -76, 34): Suggests that top-down bias from control regions to precuneus is not effective or sufficient when color words are present

- II. Conflict regressor (I > C):
2 conflicting sources vs. 2 congruent sources of color information

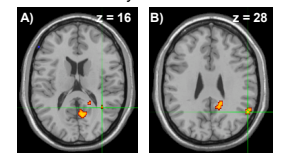
Association driven by decreased activity in C blocks



- A) L. superior frontal gyrus (BA8; -26, 44, 44): Top-down bias toward ink color is not self-initiated during "easier" congruent trials
- B) Bilateral caudate (-10, 12, 14; 14, 12, 12): May reflect increased task-irrelevant thought or sensory processing during I block

B. Event-Related Analyses:

- I. Incongruent regressor (I > N):
reflects within-block responses to conflict and trial difficulty



- A) R. superior temporal gyrus (BA22; 38, -52, 16): As hyperactivity increases, I trial activity increases and N trial activity decreases. Suggests that visual attention is engaged selectively to incongruent trials
- B) R. supramarginal gyrus (BA40; 56, -56, 28): As hyperactivity increases, N trial activity decreases. Suggests that attention is not sustained across neutral trials during the incongruent block

Suggests that hyperactive symptoms are related to an increased tendency to engage attention reactively in the face of attentional demands

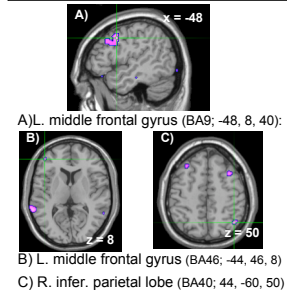
Imaging Results (cont.)

2. Inattentive Symptoms:

Blocked Analyses:

- Competition regressor (I+C > N):
2 sources of color information vs. 1 source

Association driven by decreased activity in I & C blocks.

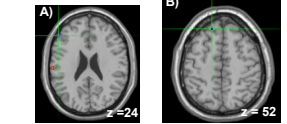


- A) L. middle frontal gyrus (BA9; -48, 8, 40): Suggests that inattentive symptoms are related to insufficient activation of frontoparietal network in situations when individuals must distinguish task-relevant vs. distracting information
- B) L. middle frontal gyrus (BA46; -44, 46, 8)
- C) R. infer. parietal lobe (BA40; 44, -60, 50)

Suggests that inattentive symptoms are related to insufficient activation of frontoparietal network in situations when individuals must distinguish task-relevant vs. distracting information

Event-Related Analyses:

- Incongruent regressor (I > N):
reflects within-block responses to conflict and trial difficulty



- A) left middle frontal gyrus (BA46; -52, 36, 24): As inattention increases, I trial activity decreases. Suggests that control-related response to conflict fails for I trials.
- B) left superior frontal gyrus (BA8; -14, 38, 52): As inattention increases, I trial activity decreases and N trial activity increases. Suggests that, as inattention symptoms increase, reactive control processes are not recruited differentially for I trials.

Suggests that inattentive symptoms are related to insufficient executive control on a trial-by-trial basis, even when attentional demands are high

Conclusions:

Even though hyperactive and inattentive symptoms were positively correlated in this sample, their relationships with brain activity appear to dissociate.

Hyperactivity Symptoms

- As hyperactivity increases, activity in executive control regions increases for neutral, but not for incongruent or congruent blocks.
- We suggest that hyperactivity reflects inefficient top-down bias from executive control regions toward task-relevant processing.

- The more hyperactive an individual, the more transient responses to incongruent trials, and less transient responses to neutral trials.
- 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 attentional set.

Inattentive Symptoms

- As inattention increases, activity in executive control regions decreases when words contain color-related information (I & C blocks).
- We suggest that inattention may arise from insufficient maintenance of executive control processes under difficult or taxing conditions.

- The more inattentive an individual, the less transient responses to incongruent trials.
- These findings suggest that inattention may also be indicative of an inability to engage reactive control mechanisms in the face of attentional demands.

See also: Poster 122 (Monday P.M.) Dysfunction in maintaining tonic aspects of an attention set in adults with ADHD

Poster 467 (Tuesday A.M.) Gray matter differences in young adults with ADHD: A pilot study using voxel-based morphometry

Supported by NIMH Grant # R01 MH070037