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Research Article

INVESTIGATE THE RELATIONSHIP BETWEEN ATTENTION DEFICIT HYPERACTIVITY DISORDER AND STUDENTS PERFORMANCE

***Samaneh Kia**
Department of Art in Psychology, University of Yazd, Yazd, Iran
**Author for Correspondence*

ABSTRACT
To examine patterns of executive dysfunction associated with ADHD, 196 children (90 ADHD, 106 controls) ages 7–11 years were administered with selected subtests from the Delis-Kaplan Executive Function System (D-KEFS). Children with ADHD performed significantly worse than controls on measures of both basic (less executive demand) skills and those with more executive demand from the Color-Word Interference and Tower subtests; however, no group differences were noted on any of the D-KEFS contrast scores. The purpose of the present study was to examine group (ADHD vs. control), sex, and ADHD subtype differences in executive function, measured by the primary *summary* and *contrast* scores on selected tests from the Delis-Kaplan Executive Function System (D-KEFS; Delis, Kaplan, & Kramer, 2001). In addition, the study sought to determine whether boys (vs. girls) with ADHD are best discriminated from their sex-specific controls by *different* sets of executive function tests.

Keywords: *Attention Deficit Hyperactivity Disorder*

INTRODUCTION
Attention deficit hyperactivity disorder (ADHD), one of the most common neurodevelopmental disorders in children, often persists in childhood with an established prevalence between 2.5 and 4.9% (Faraone *et al.*, 2006; Simon *et al.*, 2009). In children, the disorder is characterized by increased distractibility and difficulties sustaining attention, impulsiveness and hyperactivity with a subjective feeling of inner restlessness (Biederman and Faraone, 2005; Bush, 2010).

Some newer models of ADHD commonly suggest that executive dysfunction, rather than attention, is the core deficit in ADHD (Barkley, 1997; 2000), and may potentially serve as a neurobehavioral domain that differentiates between different groups of children with ADHD (e.g., groups based on sex or subtype). Executive function involves developing and implementing an approach to performing a task that is not habitually performed (Mahone *et al.,* 2002a); children with ADHD often demonstrate poor planning and organization as well as impaired response inhibition (Durston, 2003). While there is support that performance-based tests of executive function may be *sensitive* to the presence of ADHD (i.e., accurately identifying true positives), there is less evidence supporting their *specificity* (i.e., accurately rejecting true negatives).

For example, a meta-analytic review of 18 studies examining tests of executive function in children with ADHD found that motor inhibition, working memory, vigilance, and perceptual speed (automaticity) were most sensitive in differentiating children with ADHD from controls; in contrast, tests of verbal memory and visuospatial ability were least sensitive (Pennington & Ozonoff, 1996).

The research literature examining ADHD subtype differences has also yielded mixed results, with many studies reporting few or no neuropsychological differences among subtypes (e.g., Carlson, Lahey, & Neeper, 1986; Pasini *et al*., 2007).

Schmitz *et al*., (2005) noted that among children with ADHD, those with the Inattentive subtype were impaired (relative to controls) on the Stroop Test, while those with Combined subtype were impaired on measures involving planning and set-shifting (Wisconsin Card Sorting), while both subtypes demonstrated deficits (relative to controls) on Digit Span. Similarly, Nigg, Blaskey, Huang-Pollock and Rappley (2002) found that children with the combined subtype had impaired planning relative to the Inattentive subtype. Overall, there is little consensus regarding an identifiable pattern of performance among ADHD subtypes—a finding that may be complicated by sex differences in patterns of symptomatology.

Attention-Executive Deficits in ADHD Children

Attention-executive dysfunction characterized by deficits in response inhibition, error monitoring, attentional disengagement, attentional networks, and motivational style (delay aversion) in children with ADHD (Pennington & Oznoff, 1996; Gupta *et al.,* 2006, for reviews). Barkley (1997) suggested that response inhibition is the primary deficit in ADHD, which in turn affects the other executive functions. The evidence supporting a deficiency in behavioral inhibition in ADHD comes from studies that used motor inhibition tasks, such as go-no-go task (Iaboni *et al.,* 1995), the stop-signal task (Oosterlaan & Seregant, 1998), and delayed response tasks (Sonuga-Barke *et al.,* 1992). Further support for deficient inhibitory control in ADHD is suggested by neuroimaging research indicating both structural and functional deficits in the right inferior frontal cortex (Aron & Poldrack, 2005). Schachar *et al.,* (2004) studied error monitoring by looking at the slowing of responses after inhibition error (PES) in a Stop-Signal task. ADHD children slowed to a lesser extent after fewer inhibition failures suggesting deficits in error detection as well as in behavioral adjustment to errors. Cepeda *et al.,* (2000) suggested that ADHD children show deficient control processes necessary for disengagement from one task and preparation for a subsequent task.

Most of the studies have examined the development of attentional processes in normal children. Very few studies have investigated the development of attentional processes in ADHD children. To our knowledge only one study has examined the development of attentional processes particularly selective attention in ADHD children compared to normal children aged between 6-11 years (Brodeur & Pond, 2001). In this study, two groups of children (Sample group and Test group) with ADHD and normal children were tested using a timed computer task. The task consisted of identifying visual target stimuli under various distracter conditions. Children with ADHD were less efficient on the selective attention task than were children without ADHD, and older children were more efficient than younger children in both groups. It should be noted in this study reported delay in the structural development of the brain in ADHD. There is no evidence on delay in functional maturation of the brain and cognitive processes in ADHD. In other words, it is still an open question whether ADHD is characterized by a delay in normal ongoing development of, or a stable deficit in control processes (Brocki & Bohlin, 2006).

MATERIALS AND METHODS

Method

Participants

90 children with ADHD (N = 90; 48 boys) and 90 normal children (N = 90; 42 boys) in the age range of 7-11 years participated in the study. Participants were recruited from two districts of 5^{th} and 16^{th} zone of Tehran. The participants with ADHD were referred by consultant psychiatrists. Both the groups were matched on socioeconomic status. Practicing psychiatrists referred children with ADHD. All the participants with ADHD fulfilled the DSM-IV (APA, 1994) criteria for combined type ADHD. They scored the clinical cut-off (T>60) on Conners Parents Rating Scale-Revised Long form (CPRS-R:L, Conners, 2002). CPRS-R:L was also used to rule out any behavioral and attentional problems in normal children. 20% participants with ADHD had a co-morbid diagnosis of ODD. Numbers of children with co-morbid ODD were equally distributed across the different age groups and this subgroup did not differ in performance profile from the pure ADHD group. Therefore, data from children with pure ADHD as well as those with ADHD with comorbid ODD were analyzed together as a one group. All the children were average or above average in intellectual functions with scores in the range of 50-95 percentile on Colored Progressive Matrices (CPM) (Raven *et al.,* 1998).

Procedures

Executive function was assessed using the D-KEFS (Delis *et al.,* 2001). The D-KEFS was developed to assess key components of executive functions through well-established tests from the literature, with the advantage of the normative national sample being consistent across tests. The standardization sample was divided into 6 age groups consisting of separate norms for ages 7 through 10, then group normative data for the ages 7–11 and every decade thereafter. Four of the eight tests from the D-KEFS were selected for this study based on their demonstrated utility in the literature to assess different aspects of executive functions in child populations (e.g., attention, inhibition, planning, organization): Trail Making, Verbal Fluency, Color-Word Interference and Tower tests. Furthermore, each of these tests generates Summary, Contrast, and Optional scores.

Data Analysis

Group Comparisons (ADHD versus Control) on Executive Function Measures (D-KEFS)

Factorial MANOVAs (ANOVA for Tower) yielded no significant main effects for sex and no significant group-by-sex interactions. There were also no significant main effects for group on Trail Making $F(10,110) = 0.9$, $p = 0.52$ or Verbal Fluency $F(6,113) = 1.9$, $p = 0.09$. There was a significant multivariate effect for group on Color-Word Interference $F(7,112) = 3.0$, $p< 0.01$. Subsequent ANOVAs revealed that children with ADHD performed significantly worse than controls on the Color Naming $F(2,119) = 14.8$, $p< 0.01$, Word Reading $F(2,119) = 6.3$, $p = 0.01$, Inhibition $F(2,119) = 13.7$, $p< 0.01$, Inhibition Switching $F(2,119) = 12.9$, $p< 0.01$, and Combined Color Naming and Word Reading $F(2,119) = 13.4$, $p< 0.01$ variables from Color-Word Interference. Similarly, on the Tower test (Total Achievement), children with ADHD performed significantly worse than controls $F(1,118) = 8.9$, $p< 0.01$

Control					**ADHD**				**p**	**d**
Boys (n=55)			**Girls (n=51)**		**Boys (n=48)**		**Girls (n=42)**			
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**0.000**	**0.71**
CN-*	11.2	1.7	11.7	2.1	10.1	2.3	11.1	3.7	0.014	0.51
WR-*	10.4	1.9	12.1	2.4	9.7	2.1	10.7	2.8	0.000	0.63
IN-*	11.8	2	11.3	1.9	9.7	1.8	9.3	3.3	0.000	0.71
IS-*	12.1	1.7	11.8	1.4	10.5	1.4	10.3	2.1	0.000	0.69
COMB-*	9.8	1.6	11.8	1.9	10.4	2.1	11.2	2.4	0.000	0.48
CON1	9.6	1.8	10.1	2	9.2	2.5	9.7	1.8	0.649	0.08
CON2	9.5	2	9.8	2.4	9.7	1.8	10	1.9	0.823	0.00
CON3	10.1	1.9	9.6	1.9	10	1.5	9.5	2.4	0.812	0.00
TA-*	11.1	1.7	11.1	1.7	0.95	1.9	10.23	1.9	0.003	0.53

Effect size (Cohen's *d*) for group comparison (ADHD vs. TD). CN = Color Naming SS; WR = Word Reading SS; IN = Inhibition SS; IS = Inhibition-Switching SS; COMB = Color Naming + Reading SS; CON1 = Inhibition vs. Color Naming SS; CON2 = Inhibition-Switching vs. COMB; CON3 = Inhibition-Switching vs. Inhibition SS; TA = Total Accuracy Scaled Score. *TD > ADHD (total) $p< .01$.

Conclusion

Even though performance was significantly lower among children with ADHD and controls on variables from two D-KEFS tests, it is important to acknowledge that our group of children with ADHD was not *deficient* on any test—and performed consistently in the average range. This finding was not surprising given that the mean IQ of the ADHD group was solidly in the average range (82% had FSIQ > 100; 55% had FSIQ > 110).

Given that performance-based measures of executive function tend to be less sensitive in children with above average IQ (Mahone *et al.*, 2002b), the group effect sizes may be larger among samples with a wider range of IQ, or among samples of children with ADHD in which a wider range of learning and psychiatric comorbidities are included. Because we purposely recruited children with relatively "pure" ADHD as part of a larger study examining neuroimaging correlates, the severity of executive dysfunction and range of IQ typically observed among clinical groups may have been minimized, thus, potentially limiting the generaliziability of findings to the population of children with ADHD with a wider range of comorbidities.

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