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Prediction of ADHD in boys and girls using the D-KEFS

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Abstract

To examine patterns of executive dysfunction associated with ADHD, 123 children (54 ADHD, 69 controls) of ages 8–16 years were administered 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. Most subtype comparisons yielded no differences; however, children with the Combined subtype outperformed children with the Inattentive subtype on measures of both basic and executive skills from the Trail Making Test. Children with ADHD demonstrate executive dysfunction that is identified by D-KEFS summary, but not contrast scores. In this carefully screened sample of children with ADHD, few significant differences were found between groups suggesting limited sensitivity or specificity of the D-KEFS for classifying children with ADHD.

Keywords: ADHD; Subtype; Executive function; Classification; Children; Pediatrics

Attention Deficit Hyperactivity Disorder (ADHD) is a neuropsychiatric disorder with an onset in early childhood (DSM-IV-TR; American Psychiatric & Association, 2000). Research on ADHD has identified three core areas of behavioral dysfunction: sustained attention, impulsivity, and hyperactivity, with DSM-IV-TR classifications highlighting combinations of these behaviors (Predominately Inattentive Type, ADHD-I; Predominantly Hyperactive-Impulsive Type, ADHD-HI; and Combined Type, ADHD-C; American Psychiatric & Association, 2000).

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., 2002); 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

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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).

Clinically (considering symptom patterns) and cognitively (based on neuropsychological test performance), boys manifest ADHD *differently* than girls (Denckla, 1996; Gaub & Carlson, 1997). Boys are diagnosed more often than girls; however, when diagnosed, girls manifest the Inattentive subtype more often than boys (Biederman et al., 2002; Weiler, Bellinger, Marmor, Rancier, & Waber, 1999). Sex differences in neuropsychological presentation of ADHD are less clear, with some research identifying no differences between boys and girls with ADHD (e.g., Biederman et al., 2005) and others reporting inconsistent differences (Gaub & Carlson, 1997). Rucklidge and Tannock (2002), for example, reported greater impairment among boys (vs. girls) with ADHD on tests of response inhibition and processing speed. Motor impairment in boys with ADHD has been well documented (Mostofsky, Newschaffer, & Denckla, 2003), with associated neuroimaging findings implicating decreased volume in premotor, as well as prefrontal, regions (Mostofsky, Cooper, Kates, Denckla, & Kaufmann, 2002). In contrast, girls with ADHD may manifest more "cognitive" impairment than boys. Meta-analyses by Gaub and Carlson (1997) and Gershon (2002) both concluded that while girls with ADHD show lower levels of diagnostic symptomatology (hyperactivity, externalizing behavior), they manifest greater cognitive dysfunction (based on IQ scores).

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, Paloscia, Alessandrelli, Porfirio, & Curatolo, 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.

The majority of research using neuropsychological tests to quantify executive dysfunction in ADHD has emphasized "total" or "summary" measures (i.e., those in which multiple components of the executive process are incorporated into one score). In contrast, there is limited support for the validity of the "process" scores (i.e., those which directly examine organizational strategies and interfering behaviors) or "contrast" scores (i.e., those which directly compare performance between tests with low vs. high demand for executive control) in children. In one study, Mahone, Koth, Cutting, Singer, and Denckla (2001) reported that, compared to controls, children with ADHD or Tourette syndrome had higher rates of intrusion errors on the initial CVLT-C learning trials (*process* examination), even though their total summary scores did not differ. Further, in an early attempt to examine *contrast* scores, Reader, Harris, Schuerholz, and Denckla (1994) examined intra-individual discrepancies between a pair of content-matched tests of posterior versus anterior brain functioning and found that children with ADHD performed significantly better on tasks involving posterior functioning (with less executive function demands) rather than anterior (with greater executive function demands). Therefore, examination of process and contrast scores may provide additional information in describing executive dysfunction among children with ADHD, and may be sensitive to differences that are not captured by the total or summary scores; however sufficient research to support these relationships remains unexamined.

1. Purpose

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 et al., 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. We used the D-KEFS to examine these research questions for three reasons: (1) it is a relatively new measure that has incorporated many of the "classic" executive function tests in a co-normed battery; (2) the D-KEFS uses combined sex norms, and performance of children with ADHD has not been examined on this measure considering the differential effects of sex; (3) while the D-KEFS generates summary, process, and contrast scores for all its subtests, the validity of these scores in children with ADHD has not yet been demonstrated.

Three specific hypotheses were examined in the present study: First, compared to controls, it was hypothesized that children with ADHD would perform more poorly on the D-KEFS summary and contrast measures. Second, within the ADHD group, it was hypothesized that sex and subtype differences would be noted in performance on measures from the D-KEFS, with boys and children with the Combined Subtype demonstrating poorer relative performance. Third, it was hypothesized that the specific tests that best discriminated ADHD and control groups would be different in boys and girls, with measures emphasizing processing speed and inhibition emerging as more salient predictors among boys.

2. Method

2.1. Participants

After approval from the Johns Hopkins Medicine Institution Review Board, participants were recruited from outpatient clinics at the Kennedy Krieger Institute, and from local area pediatricians, local chapters of Children and Adults with Attention-Deficit/Hyperactivity Disorder (CHADD), schools, social/service organizations (e.g., Boy/Girl Scouts), and advertisements in the community (e.g., postings at libraries). This study is part of a larger project examining brain–behavior relationships in children; therefore, children were screened for most common comorbidities (detailed below). All children entering the study met the following the criteria: (1) between 8 years–0 months and 16 years–11 months; (2) full scale IQ estimate of 80 or higher based on a standardized IQ test given either during a prior school assessment (completed within 1 year of study assessment) or on the Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV; Wechsler, 2003) given at time of testing; (3) no history of speech/language disorder or a Reading Disability (RD) either screened out before a visit or based on prior school assessment (completed within 1 year of the current assessment). RD was based on a statistically significant discrepancy between a child's Full Scale IQ score and his/her Word Reading subtest score from the Wechsler Individual Achievement Test, Second Edition (WIAT-II, Wechsler, 2002), or a standard score below 85 on the Word Reading subtest, regardless of IQ score; and (4) no evidence of visual or hearing impairment, or history of other neurological or psychiatric disorder.

A total of 54 children were included in the ADHD group. Diagnosis of ADHD was determined by a structured parent interview that utilized DSM-IV criteria (Diagnostic Interview for Children and Adolescents, Fourth Edition, DICA-IV; Reich, Welner, & Herjanic, 1997) and administration of ADHD-specific and broad behavior rating scales (Conners' Parent Rating Scale-Revised, Long Form, CPRS; Conners, 1997). Children with DSM-IV diagnoses other than Oppositional Defiant Disorder (ODD; $n = 6$) or Specific Phobias ($n = 7$) were excluded. DSM-IV criteria were used to diagnose ADHD and evaluate for all three ADHD subtypes (ADHD-I, ADHD-HI, and ADHD-C). Classification of ADHD subtype was made based on DICA-IV interview and rating scales. Children were assigned to the ADHD-I group if they met criteria for inattentiveness but *not* hyperactivity/impulsivity on the DICA-IV, and a T-score of 65 or greater on the CPRS Scale L (DSM-IV criteria for Predominantly Inattentive Type), and a T-score of 60 or less on the CPRS Scale M (DSM-IV criteria for Predominantly Hyperactive-Impulsive Type). Children were assigned to the ADHD-HI if they met criteria for hyperactivity/impulsivity but *not* inattention on the DICA-IV, and a T-score of 65 or greater on the CPRS Scale M (DSM-IV criteria for Predominantly Hyperactive-Impulsive Type) and a T-score of 60 or less on the CPRS Scale L (DSM criteria for Predominantly Inattentive Type). All other children who met criteria for ADHD were assigned to the ADHD-C group. Only 2 children were diagnosed with ADHD-HI, consequently, the ADHD-C and ADHD-HI groups were combined for subtype analyses. Every attempt was made to match the groups on the basis of age, FSIQ, sex, and race. Children with ADHD taking psychoactive medications other than stimulants were excluded. To minimize the likelihood of confound between sex and subtype, we *oversampled* for the type of ADHD less likely to occur in each sex. Specifically, we recruited girls with Combined subtype (to comprise at least 40% of the sample), and boys with Inattentive subtype (to comprise at least 40% of the sample).

Children in the control group ($n = 69$) were recruited through the local school district and flyers posted in the community. Controls were additionally required to meet the following criteria: (1) no history of mental health services for behavior or emotional problems; (2) no parent or teacher report of previous diagnosis of Conduct Disorder (CD); (3) *T*-scores 60 or below on the ADHD (DSM-IV Inattention; DSM-IV Hyperactivity) subscales of the CPRS (Conners, 1997); (4) no history of academic problems requiring school based intervention services or history of defined primary reading or language-based learning disability, as established through medical history, psychological testing, or parental and teacher interview.

2.2. Procedures

Prior to scheduling the appointment, parents of participants were briefly interviewed over the telephone in order to obtain demographic information, referral source, school and developmental history. If the child was determined to be eligible via the brief screen, the DICA-IV was administered by phone prior to scheduling an appointment for testing. Parents of children taking stimulants were asked to withhold the child's medication on the day of and day prior to testing. On the day of the appointment, parents completed questionnaires and rating scales while their child was being tested. During the 2.5 h appointment, children were administered the following standardized measures: WISC-IV (if no prior estimate of intelligence was available), Word Reading from the WIAT-II, and four tests from the D-KEFS.

Executive function was assessed using the D-KEFS (Delis, Kaplan, & Kramer, 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 (1750 children and adults). The standardization sample was divided into 16 age groups consisting of separate norms for ages 8 through 15, then group normative data for the ages 16–19 and every decade thereafter (e.g., 20–29, 30–39, etc.). 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 (similar to Stroop Test, Stroop, 1935), and Tower tests. Furthermore, each of these tests generates Summary, Contrast, and Optional scores. The tests are described in detail in the D-KEFS manual, and an outline of primary summary and contrast measures analyzed in the current study is provided in Table 1; optional scores were not examined as part of the present study.

2.3. Data analyses

First, three separate 2 × 2 factorial MANOVAs were used to examine group and sex differences for the primary scaled scores generated for the Trail Making, Verbal Fluency, and Color–Word Interference tests (including both summary and contrast scores). Significant multivariate results were followed by univariate tests. Since the Tower test had only one primary score, a factorial ANOVA was used to examine performance for that subtest. Second, within the ADHD sample, subtype (inattentive vs. combined) differences on each test were analyzed using ANOVAs. Effect size values were computed using the d statistic. Effect size is a standardized quantitative index that can represent the magnitude of change that one variable produces in another variable as reflected in the difference between two means, independent of sample size (Cohen, 1988). Interpretation of the effect size d was based on a convention suggested by Cohen, such that 0.20 is considered a "small" effect size, 0.50 considered "medium," and 0.80 or greater, a "large" effect size. Given multiple comparisons, to protect against Type I error, a more conservative approach to interpretation was applied, such that results were only interpreted as significant with $p < 0.01$ and an effect size (Cohen's d) of 0.50 or greater. Third, standard scores from all primary measures (summary, contrast) for the Trail Making, Verbal Fluency, Color Word, and Tower tests were entered into sex-specific linear discriminant function analyses. The sample was initially examined for normality, and several variables were negatively skewed. For those skewed variables, outliers (i.e., data points that were more than ±3S.D. from the mean) were truncated to the value at ±3S.D. After this transformation, these variables were no longer skewed.

3. Results

3.1. Demographic information

Demographic information for the sample is provided in Table 2. The total sample was drawn from a largely middle class SES and was predominantly Caucasian, with a slight predominance for boys. Children ranged in age from 8 to 16 years. There were no significant differences between ADHD and control groups in distribution of sex, race, or handedness, and no significant group differences in SES. Children in the control group had significantly higher FSIQ scores than the ADHD group $F(1,121) = 9.90$, $p < 0.01$, while children with ADHD were also significantly older than controls $F(1, 121) = 5.00$, $p = 0.03$. Because group comparisons were made using age-corrected standard scores, age was not used as a covariate for group comparisons. IQ was not used as a covariate for group comparisons, as it seems

Table 1
D-KEFS variables included in the study

D-KEFS test/variable	Type of measure
Trail making test	
Primary measures: completion times	
Condition 1: visual scanning	Total-ingredient
Condition 2: number sequencing	Total-ingredient
Condition 3: letter sequencing	Total-ingredient
Condition 4: number-letter switching	Total-executive
Condition 5: motor speed	Total-ingredient
Primary combined measure: completion times	
Combined number + letter sequencing	Summary-ingredient
Primary contrast measures: completion times	
Switching vs. visual scanning	Contrast
Switching vs. number sequencing	Contrast
Switching vs. letter sequencing	Contrast
Switching vs. combined number + letter sequencing	Contrast
Switching vs. motor speed	Contrast
Verbal fluency	
Primary measures	
Letter fluency	Total-executive
Category fluency	Total-ingredient
Category switching	Total-executive
Category switching: total switching accuracy	Total-executive
Primary contrast measure	
Letter fluency vs. category fluency	Contrast
Category switching vs. category fluency	Contrast
Color word interference	
Primary measures: completion times	
Condition 1: color naming	Total-ingredient
Condition 2: word reading	Total-ingredient
Condition 3: inhibition	Total-executive
Condition 4: inhibition/switching	Total-executive
Primary combined measure: completion times	
Combined naming + reading	Summary-ingredient
Primary contrast measures: completion times	
Inhibition vs. color naming	Contrast
Inhibition/switching vs. combined naming + reading	Contrast
Inhibition/switching vs. inhibition	Contrast
Tower	
Primary measure	
Total achievement score	Total-executive

circular to control for IQ measurements that may be substantially determined by disorder itself and IQ test scores may be lowered by ADHD-associated deficits (Barkley, 1997; Mahone et al., 2003).

Based on DICA-IV interviews and rating scales, children with all three subtypes of ADHD were included (i.e., ADHD-C, $n = 33$; ADHD-H/I, $n = 2$; ADHD-I, $n = 19$), and were combined into one group for initial analyses. Demographic information by ADHD subtype is provided in Table 3. To examine performance by ADHD subtype, two ADHD subtype groups were formed: Inattentive ($n = 19$) and Combined + Hyperactive-Impulsive ($n = 35$). The proportion of girls was similar in these two subtype groups, and there were no significant differences in FSIQ between subtypes. While gender-based differences in ADHD subtype are recognized, the current sample had insufficient numbers of participants in each cell to appropriately examine sex by subtype interactions.

Table 2
Demographic information

	Control						ADHD					
	Boys ($n = 35$)		Girls ($n = 34$)		Total ($n = 69$)		Boys ($n = 32$)		Girls ($n = 22$)		Total ($n = 54$)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Age*	11.1	1.7	11.0	2.2	11.0	1.9	12.4	2.1	11.0	2.1	11.8	2.2
SES	51.5	11.2	54.7	8.4	53.1	9.9	54.8	10.8	55.2	7.8	54.9	9.6
FSIQ**	115.9	12.4	114.9	10.3	115.4	11.3	107.8	13.5	110.8	14.1	109.0	13.7
Age 8–10 years	$n = 19$		$n = 16$		$n = 35$		$n = 8$		$n = 12$		$n = 20$	
Age 11–13 years	$n = 15$		$n = 16$		$n = 31$		$n = 17$		$n = 7$		$n = 24$	
Age 14–15 years	$n = 1$		$n = 2$		$n = 3$		$n = 7$		$n = 3$		$n = 10$	
Caucasian	$n = 25$		$n = 26$		$n = 51$		$n = 27$		$n = 16$		$n = 43$	
African American	$n = 5$		$n = 4$		$n = 9$		$n = 3$		$n = 2$		$n = 5$	
Hispanic	$n = 1$		$n = 0$		$n = 1$		$n = 0$		$n = 1$		$n = 1$	
Asian	$n = 1$		$n = 0$		$n = 1$		$n = 1$		$n = 1$		$n = 1$	
Other	$n = 3$		$n = 2$		$n = 5$		$n = 0$		$n = 1$		$n = 1$	

Note: ADHD = attention deficit hyperactivity disorder; TD = typically developing; SES = Hollingshead index; SES data not available for 5 participants in the TD group and 6 in the ADHD group.
* TD < ADHD, $p < 0.05$.
** TD > ADHD, $p = 0.01$.

There were no significant differences between boys and girls in race distribution, handedness, or proportion with ADHD diagnosis. In the entire sample, boys were significantly older than girls $F(1, 122) = 4.33$, $p = 0.04$; however, there were no significant differences between the sexes in SES or FSIQ for the entire sample.

3.2. Group comparisons (ADHD vs. 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 $F(7,112) = 3.0$, $p < 0.01$ (see Table 4). 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 $F(1,118) = 8.9$, $p < 0.01$ (Table 4).

3.3. ADHD subtype comparisons on executive function measures (D-KEFS)

Children with Inattentive subtype performed significantly worse than those with Combined subtype on Number Sequencing $F(2, 49) = 7.09$, Letter Sequencing $F(2,49) = 8.03$, and Combined Number-Letter Sequencing $F(1,50) = 8.39$ conditions of the Trail Making test (Table 5). There were no other significant subtype differences

Table 3
Demographic information by ADHD subtype

	Inattentive ($n = 19$)		Combined + hyperactive-impulsive ($n = 35$)	
	Mean	S.D.	Mean	S.D.
Age	11.8	2.2	11.7	2.0
SES	53.9	8.1	55.2	10.4
FSIQ	105.5	12.4	109.0	12.7
Percent male	57.9	–	58.8	–

Note: SES = Hollingshead Index; all comparisons n.s.

Table 4
D-KEFS tests yielding significant group differences

	Control						ADHD						p	d[a]
	Boys ($n = 35$)		Girls ($n = 34$)		Total ($n = 69$)		Boys ($n = 32$)		Girls ($n = 22$)		Total ($n = 54$)			
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.		
Color word interference														
CN*	11.5	1.7	12.2	2.7	11.9	2.3	9.4	3.7	10.3	3.3	9.8	3.5	0.000	0.71
WR*	11.9	2.0	11.8	1.6	11.9	1.8	10.4	2.9	11.3	2.3	10.8	2.7	0.014	0.48
IN*	11.7	2.0	11.8	2.1	11.8	2.0	9.8	3.4	10.4	2.2	10.0	3.0	0.000	0.71
IS*	11.6	1.7	11.9	2.0	11.7	1.9	9.7	3.3	10.6	2.1	10.0	2.9	0.000	0.69
COMB*	12.0	1.6	12.2	1.6	12.1	1.6	10.1	3.0	11.1	2.5	10.5	2.8	0.000	0.70
CON1	10.3	1.7	9.8	2.5	10.0	2.1	10.3	2.9	10.1	2.5	10.2	2.7	0.644	0.08
CON2	9.6	1.8	9.7	1.7	9.6	1.7	9.6	3.0	9.6	2.3	9.6	2.7	0.837	0.00
CON3	98	2.1	10.1	1.9	10.0	2.0	9.9	2.8	10.2	1.7	10.0	2.4	0.818	0.00
Tower														
TA*	11.1	1.8	11.5	1.7	11.3	1.7	10.5	1.9	10.1	1.9	10.3	1.9	0.003	0.55

Note: ADHD = Attention deficit hyperactivity disorder; 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.

[a] Effect size (Cohen's d) for group comparison (ADHD vs. TD).

* TD > ADHD (total), $p < 0.01$.

noted on any other scores (summary or contrast) from Trail Making, Verbal Fluency, Color–Word Interference, or Tower.

3.4. Group classification using the D-KEFS

3.4.1. Girls

Using stepwise linear discriminant function analysis to predict group membership in girls, the discriminant function produced a significant degree of dissimilarity between the girls with ADHD and female controls (Wilks' Lambda = 0.83; $p < 0.01$), and the canonical correlation between the discriminant function and group membership was 0.48. Using the criteria of $F = 3.85$ to enter and 2.71 to remove, only two tests entered into the function: Tower Total Achievement

Table 5
Performance on the trail making test by ADHD subtype

	Inattentive ($n = 19$)		Combined/hyperactive-impulsive ($n = 35$)		p	d[a]
	Mean	S.D.	Mean	S.D.		
VS	8.8	2.2	10.4	2.6	0.029	0.71
NS*	9.1	3.3	11.3	2.3	0.007	0.87
LS*	8.1	4.4	11.0	3.0	0.007	0.87
LN	9.3	2.7	10.3	3.2	0.263	0.39
MS	9.3	3.6	10.0	2.9	0.440	0.26
COMB*	9.0	4.2	11.8	2.7	0.005	0.91
CON1	10.6	2.6	10.0	2.7	0.456	0.19
CON2	10.2	3.3	9.1	3.0	0.216	0.34
CON3	11.2	3.7	9.3	3.0	0.053	0.56
CON4	10.4	3.7	8.6	3.0	0.058	0.56
CON5	10.0	2.9	10.3	3.4	0.770	0.12

Note: VS = Visual Scanning SS; NS = Number Sequencing SS; LS = Letter Sequencing SS; LN = Letter-Number Sequencing SS; MS = Motor Speed SS; COMB = Number + Letter Sequencing SS; CON1 = Switching vs. Visual Scanning SS; CON2 = Switching vs. Number Sequencing SS; CON3 = Switching vs. Letter Sequencing SS; CON4 = Switching vs. COMB; CON5 = Switching vs. Motor Speed SS.

[a] Effect size (Cohen's d) for group comparison (ADHD-I vs. ADHD-C/HI).

* ADHD-C/HI > ADHD-I, $p < 0.01$.

summary score made the largest contribution in discriminating girls with ADHD from female controls, followed by the Trail Making test (Switching vs. Number Sequencing contrast score). Using this function, the computed discriminant score for each girl was used to classify her according to probable membership in the ADHD or control group. The cutoff point (−0.11) was midway between the mean discriminant scores for the ADHD and control groups (−0.57 and 0.35, respectively). Children with a discriminant score lower than −0.11 were classified as probably ADHD and those scoring higher, as probably control. Using this cutoff for the sub-sample of girls, 67.3% of girls in either ADHD or control groups were correctly classified in the appropriate group; positive predictive power was 0.60 and negative predictive power was 0.71.

3.4.2. *Boys*

Using stepwise linear discriminant function analysis to predict group membership in boys, the discriminant function produced a significant degree of dissimilarity between the boys with ADHD and male controls (Wilks' Lambda = 0.90; $p < 0.01$), and the canonical correlation between the discriminant function and group membership was 0.37. Using the criterion of $F = 3.84$ to enter and 2.71 to remove, the only test to enter into the discriminant function was the Combined Color Naming + Reading Composite score. Using this function, the computed discriminant score for each boy was used to classify him according to probable membership in the ADHD or control groups. The cutoff point (−0.04) was midway between the mean discriminant scores for the ADHD and control groups (−0.37 and 0.29, respectively). Boys with a discriminant score lower than −0.04 were classified as probably ADHD and those scoring higher, as probably control. Using this cutoff for the subsample of boys, 58.5% of the boys were correctly classified in the appropriate group; positive predictive power was 0.55 and negative predictive power was 0.62.

4. Discussion

Results from the present study demonstrate that children with ADHD perform more poorly than controls on two of four selected measures from the D-KEFS, providing some modest support for the use of the D-KEFS to identify patterns of executive dysfunction in children with ADHD. Of note, the group differences emerged, even though groups were screened for low IQ and psychiatric comorbidities, and provided the structure of the one-to-one testing environment. Further, significant differences were observed between groups on primary *summary* measures for Color–Word Interference and Tower tests; however, despite adequate statistical power, no significant differences were observed between ADHD and control groups on *any* of the contrast measures examined in the four tests, or between girls and boys. In other words, controls outperformed children with ADHD on both the "more executive" (e.g., Color Word Inhibition) and "less executive" (e.g., Color Naming) tests, potentially highlighting the underlying executive function (response preparation) demands associated with some of these tests considered to emphasize more "basic" or "ingredient" skills. Alternatively, performance may be related to the novelty of the tasks or the rapid speed of retrieval required for success (which would be expected to be poorer in children with ADHD than controls), or because of non-executive cognitive deficits associated with ADHD. Regardless of the reason for differences, since group differences are noted in these more basic skills, the sensitivity of these contrast scores appears limited in children with ADHD.

Even though performance was significantly lower among children with ADHD than 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.

It is also noteworthy that group differences were evident on tasks assessing rapid naming speed (especially color naming), even though our group was screened for reading disorders. While rapid naming is a well-established predictor of reading skill, rapid naming deficits are not unique to children with reading disorders (Rucklidge & Tannock, 2002; Tannock, Martinussen, & Frijters, 2000). Semrud-Clikeman, Guy, Griffin, and Hynd (2000) found that children/adolescents with ADHD performed worse than controls on rapid automatized naming of colors and objects, whereas children with reading disorders were different from controls only on letters and numbers, and then only at older ages. Rapid *color* naming may be separable from other forms of rapid naming in ADHD, and likely involves a different neural substrate (Moore & Price, 1999). Color naming is considered to be more semantically based, while letter and number naming are considered more phonologically based (Wolf & Obregon, 1992). Additionally, color naming can be more difficult for some children, as the lexical and semantic demands involved in rapid naming of colors may require more effortful mental processing than word reading (Stuss, Floden, Alexander, Levine, & Katz, 2001). For example, Savitz and Jansen (2003) found that boys with ADHD performed more slowly than controls on the color naming condition of the Stroop Test. Tannock et al. (2000) found that children with ADHD (with *and* without reading disorder) were slower than controls on color naming; treatment with methylphenidate improved color naming in the ADHD groups, but did not improve naming speed for letters and numbers. Similarly, Bedard, Ickowicz, and Tannock (2002) found that children with ADHD improved on color *and* word naming following treatment with methylphenidate. These findings highlight the higher level "executive" demands that may be unique to rapid color naming tests, and underscore the vulnerability of children with ADHD to tasks requiring these skills.

There were also no significant differences observed between ADHD subtypes on *any* of the primary measures emphasizing "executive" skills, a finding consistent with more recent research on ADHD subtypes (Pasini et al., 2007). Rather, significant subtype differences were observed only on tests examining more basic or "ingredient" skills from the Trail Making test (i.e., Visual Scanning, Letter Sequencing, and Number Sequencing), with children with Inattentive subtype performing *worse* on these tests. These findings are somewhat surprising given that most of the children in the Combined subtype group also had symptoms of inattention. This may be related to the fact that the executive measures used in the present study have not only a strong attentional component, but require other skills that may be uniquely deficient in the Inattention subtype of ADHD. As no differences were noted between groups in sex or IQ, factors other than those examined in the present study could have impacted performance.

Although different patterns of classification were identified in boys and girls by discriminant function analyses, group prediction was only modest (67% and 59% accuracy for girls and boys, respectively). Given a 50% likelihood of predicting groups by chance alone, the findings argue against using these D-KEFS tests alone in predicting group membership for children with ADHD. This limitation is especially true for boys, and possibly reflects the known intercorrelations among the four D-KEFS subtests, or the low to moderate effect sizes (ADHD vs. control) for children in this age and ability range.

The strengths of the present study included the careful identification of groups, strict inclusion and exclusion criteria, and the use of co-normed measures of executive function. Further, the present study provided a direct examination of *contrast* variables, which have not been addressed in the research literature on the D-KEFS in children. There are also several issues in the present study that should be addressed. First, although the paucity of group differences noted among primary scores on the D-KEFS is informative, sample (i.e., above average IQ, comorbidities excluded) or test characteristics may explain some of the null findings. Second, it was beyond the scope of this study to examine all eight D-KEFS measures or the numerous optional scores that are derived from each D-KEFS test. Future research should examine the predictive validity of all D-KEFS measures in children with ADHD, with closer examination of these optional scores. Study of optional error and process scores may be particularly fruitful since they tend to be less correlated with summary scores than the contrast scores (Delis et al., 2001), and may contribute to predictive power more consistently than the contrast scores. In addition, future research may consider including imaging data (e.g., MRI) and additional comparison of the methods of assessing ADHD (e.g., comparison of assessment information with parent report information). Finally, future research should also continue to examine the convergent and discriminant validity of the D-KEFS via similar executive (convergent) and non-executive (discriminant) measures for comparison, as well as further distinguish the interactive effects of sex and ADHD subtype.

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