Delis-Kaplan Executive Function System Performance as Measure of Executive Dysfunction in Adult ADHD

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Abstract

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The evidence suggesting Attention-Deficit/Hyperactivity Disorder (ADHD) has neurodevelopmental roots with specific impairment in executive functioning continues to grow. However, no known study to date has explored the relationship between adult males with a diagnosis of ADHD and performance on a measure of executive functioning, the Delis-Kaplan Executive Function System (DKEFS). The current investigation attempted to explore (1) whether adult males with ADHD show an overall pattern of executive dysfunction as measured by the DKEFS, (2) potential group differences on both level-of-performance and process-oriented measure scores, and (3) the clinical utility of the DKEFS in diagnosing ADHD in adult males. A sample of 37 adults with ADHD was compared to a community sample of equal size. Multivariate statistical analysis yielded significant group differences despite intellectual advantage by the study group. In addition, analysis of individual measures revealed patterns which were not initially predicted based upon current theories of ADHD. Overall, however, no clinically significant impairments emerged, as defined by scores at least one standard deviation below the mean. These findings and potential clinical implications are discussed with recommendations for future research.

Keywords: Delis-Kaplan Executive Function System, ADHD, DKEFS, Executive Dysfunction

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Attention-Deficit Hyperactivity Disorder

Attention-Deficit/Hyperactivity Disorder (ADHD) is one of the most frequently studied and debated diagnostic categories (Rohde et al., 2005). Currently the etiology and developmental course of the disorder continues to be a pressing issue within the field. While psychosocial theories of the disorder persist, consensus is that ADHD has a neurolodevelopmental basis (Sonuga-Barke, 2005). Increasing evidence is linking core components of ADHD symptomatology to particular structures in the brain, specifically implicating the frontal cortices (Giedd, Blumenthal, Molloy, & Castellanos, 2001; Schneider et al., 2010, Stahl, 2009). To date, much of what we know about the disorder has arisen from observation and experimentation among child and adolescent populations, although what was generally known as a childhood dysfunction is gaining credibility as an adult disorder (Castellanos, Kelly, & Milham, 2009; Hervey, Epstein, & Curry, 2004). Despite these recent advancements there is not a gold standard measure for assessing ADHD in the adult population, although, as with the case of child/adolescent populations, the use of rating scales and neuropsychological measures that assess executive function is common (Adler, 2010). Toward that end the current study evaluated the utility of employing a test of executive functioning, the Delis-Kaplan Executive Function System (DKEFS) in a specific subpopulation of adults with ADHD.

Overview of ADHD

ADHD nosological origins are traced back to 1937 when Charles Bradley first began evaluating hyperkinesis in children and noted that children taking Benzedrine manifested behavioral changes (Bradley, 1937). An associate of Bradley, Marice Laufer, used the term *minimal brain dysfunction* to classify a group of children that manifested both a learning disorder and the hyperkinetic impulse disorder in the presence of average to above average intelligence (Wenar, 1994). Since that time, several different diagnostic labels have been affixed to ADHD syndrome including: hyperkinetic reaction, hyperactive child syndrome, minimal brain damage, and minimal cerebral dysfunction (Cantwell, 1985).

Today ADHD is often described as a developmental neurobehavioral disorder characterized by developmentally inappropriate degrees of inattention, impulsivity, and hyperactivity that typically develop early in childhood (before age 7 years), is relatively chronic, results in significant lifestyle impairments, and cannot be attributed to mental retardation, a pervasive developmental disorder, or psychosis (APA, 2000; Barkley, 1990). While the specific etiology of the disorder has yet to be identified, growing support in the literature suggests that ADHD is derived from a complicated relationship between psychological, neurological, environmental, and genetic proponents (Wender, 1995). The Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision (DSM-IV TR) identifies three subtypes of the disorder which are appended to the diagnostic label according to predominant features displayed by the individual: inattentive type, hyperactive-impulsive type, and combined type (APA, 2000).

The DSM-IV TR lists ADHD as a disorder first diagnosed prior to adulthood, and given the early beginnings of ADHD it is easy to see why many view it as a disorder solely afflicting children. Even a brief review of the current literature demonstrates that it has received a great deal of attention in children and adolescents. Various researchers have suggested that it is one of the most prevalent neurobehavioral conditions of childhood, stretching across cultural and national boundaries (Faraone, Sergeant, Gillberg, & Biederman, 2003). Still others report that ADHD is the most commonly diagnosed childhood disorder (Tucha et al., 2005). Currently, prevalence rates among the adolescent population are estimated to be in the range of 3-5% (APA, 2000).

Until recently, ADHD has been viewed primarily as a disorder that individuals grew out of as they matured (Faraone, Biederman, Feighner, & Monuteaux, 2000; Heiligenstein & Keeling, 1995; Shaffer, 1994); therefore, it was not studied extensively in the adult population (Tannock, 1998). Some theorized that ADHD was not an impairment due to chronic neurological deficits but rather developmental delays that would attenuate as the child matured. This maturational lag hypothesis, as it came to be known, has been supported by research suggesting that children with ADHD performed on various cognitive tasks at a level two years behind normal-aged children and that these disparate scores converge as the children mature into young adults (Rapport, VanVoorhis, Tzelpis, & Friedman, 2001). However, this maturation effect is not universal, as a large subset of children continue to manifest behaviorally significant features of the disorder into adulthood. On average, clinical studies show that between 30-50% of children with ADHD will maintain similar symptoms and impairments as adults (Mannuzza, Klein, & Addalli, 1991; Schweitzer et al., 2000; Weiss & Hechtman, 1986). Moreover, prevalence rates of adult ADHD suggest these numbers may under-estimate the number of children that continue to experience ADHD symptoms into adulthood. In their review, Kessler et al. (2006) suggest that the prevalence rate in adults is around 4.4% which is in line with the reported range for the disorder in children and adolescents. In light of these and other clinical findings, greater attention is being placed on researching ADHD in adult population.

Much of what is known about adult ADHD is based upon the framework for understanding the disorder in younger populations; ergo, the theories and experimental frameworks of the disorder in the adult population have mimicked that seen in the child/adolescent domain. While methodologies and techniques (use of rating scales, interviews, etc), and clinical treatments (medication) reported in the child/adolescent literature have made the transition into adult studies with little or no difficulty, the same cannot be said for neuropsychological findings (Hervey et al., 2004). Hervey and his colleagues propose that one possible explanation for this lack of neuropsychological transition may be due to a "lack of consensus regarding what neuropsychological deficits actually exist in children with ADHD and what are the best measures for assessing those deficits" (p. 485). Similarly, another concern is that what is being measured in children/adolescents may in fact be related to developmental issues, not neuropsychological deficits associated with ADHD.

Many studies of neuropsychological functioning in children have shown a wide variety of deficits but fail to suggest consistency across any specific domain. Despite this, there does appear to be convergence of the data in areas such as attention and working memory (Hervey et al., 2004; Trani et al., 2010). Thereby providing support that an underlying theory, such as that proposed by Barkley, is probable and in need of further substantiating evidence.

As suggested, there is currently no theory regarding ADHD and its etiology that is universally accepted. Despite this fact, there are some who have proposed theories that have significantly advanced the understanding and guided the current body of research. One of these theorists, Russell Barkley, has suggested the core deficit in both combined and hyperactive sub-type ADHD is response inhibition. In his review, Barkley (1999) defends his theory of response inhibition deficiency as a universal explanation for ADHD. Central to this theory are three interrelated sub-processes: the inhibition of an initial prepotent response to events, interrupting a current response to allow for a delay before responding, and remaining undistracted during the delay period.

The first of these, inhibition of an initial prepotent response, is characterized by the ADHD individual's response to certain events. Barkley (1999) suggests, "The prepotent response is that response for which immediate reinforcement (positive or negative) is available or has historically been associated with that response." Self-control is limited as the individual is less able to postpone responding to an event, even if the postponement promises a greater reward later. The second sub-process is concerned with the individual being able to stop in the middle of a response, creating a delay period in which critical components of the self and response can be evaluated or reassessed. Such ability is critical for self-monitoring and the incorporation of immediate feedback into problem-solving and behavior modification. The third sub-process is related to freedom from distraction in which the individual is capable of protecting the delay period that is part of the second sub-process. Once a response has been stopped and the ensuing delay period begins, the individual must be able to maintain focus on the current task and not become distracted by either external or internal factors. Failure to maintain this interference control, as Barkley calls it, results in self-dysregulation with the individual likely to resort to prepotent responding, which is often an inappropriate or ineffective response.

Barkley (1997) originally proposed that the different subtypes of ADHD might be conceptually different with different mechanisms fueling behavior. According to his theory, the impulsive-hyperactive subtype and combined subtype are likely similar, if not the same, disorder that is most directly mediated by impairments with response inhibition and affects sustained attention. Deficiencies in the response inhibition, according to Barkley, probably apply only to the hyperactive-impulsive and combined subtypes of ADHD and are not a component of the inattentive type. Barkley (1999) proposes that deficiency in the inattentive sub-type is possibly related to focus/selective attention and speed of information processing. Earlier reviews failed to find significant difference across diagnostic subtypes based upon performance on a wide variety of tests of executive functioning (see Woods, Lovejoy & Ball, 2002). Currently, there is not a clear consensus about the behavioral or cognitive profile of the different subtypes of ADHD on various objective measures of attention and executive function with mixed results still being reported in the research (Biederman et al., 2009; Cordier, Bundy, Hocking & Einfeld, 2010; Diamond, 2005; Lemiere et al., 2010; Lubke, Judziak, Derks, van Bijsterveldt, & Boomsma, 2009).

Neuroimaging and Anatomy of ADHD

The understanding of ADHD and its associated features have been greatly advanced by the development of modern scanning instruments that allow images of the brain to be produced, as well as provide visual representations of neuronal activation. The techniques most commonly used in this body of literature include: standard structural magnetic resonance imaging (MRI), single photo emission computed tomography (SPECT), functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) (Bush, Valera, & Seidman, 2005), although future studies will likely use more advance techniques such as diffusion tensor imaging (DTI) and others (Ashtari et al., 2005; Rusch et al., 2007; Russell et al., 2006; Skranes et al., 2007). A body of literature now available has begun to demonstrate anatomical differences likely implicated in ADHD disorder, and while an extensive review of the technology is not necessary, a brief description is helpful. SPECT and PET are very similar. Individuals in both procedures inhale or ingest a radioactive isotope that emits a particle of radiation that is detected and transformed into an image by a computer program. More active structures in the brain receive greater blood flow and subsequently, greater amounts of radiation are emitted and detected thereby algorithmically showing increased neuronal activity.

Unlike SPECT or PET, fMRI is a completely non-invasive neuroimaging procedure which depends upon the principles and procedures of normal MRI. In MRI large magnets create a powerful magnetic field that causes the hydrogen atoms in an individual to align. A radio wave, or radio frequency pulse, is directed through the body in the area under examination disrupting the aligned atoms. Once the pulse is discontinued, the time it takes the atoms to return to their normal spin is measured. A computer analyzes the data and an image of the structure is produced (Bremner, 2005). Areas of the brain can be volumetrically quantified and compared for differences. In fMRI measured blood oxygen levels provide information about neuronal activity. This is possible because active areas in the brain temporarily undergo anaerobic metabolism causing capillary blood flow in the active region to be more richly oxygenated than non-active regions.

Recently**,** Bush and colleagues (2005) reviewed all major imaging studies since 1984 evaluating ADHD. Based upon the review they suggested decreased global metabolism in the ADHD brain. This finding was based in large part on the work of Zametkin and colleagues (1990) who found ADHD subjects had 8.1% lower cerebral glucose metabolism compared to controls. These findings were challenged by some who criticized Zametkin’s comparison groups to be gender unbalanced (Baumeister & Hawkins, 2001; Leo & Cohen, 2003), but these same findings have been duplicated elsewhere (Castellanos et al., 2002). Furthermore, studies using SPECT technology have also found significant difference in metabolism in the dorsal anterior cingulate, motor and premotor cortices (Kim et al., 2010; Langlebon et al., 2002); right lateral prefrontal, middle temporal and cerebellum (Kim et al., 2010; Kim, Lee, Shin, Cho, & Lee, 2002); dorsal lateral prefrontal cortex, caudate and thalamus (Amen, Hanks, & Prunella, 2008; Kim, Lee, Cho, & Lee, 2001; Szobot et al., 2010); and striatum and periventricular areas (Lou, Andresen, Steinberg, McLaughlin, & Friberg, 1998; Lou, Henriksen, & Bruhn, 1990; Szobot et al., 2010).

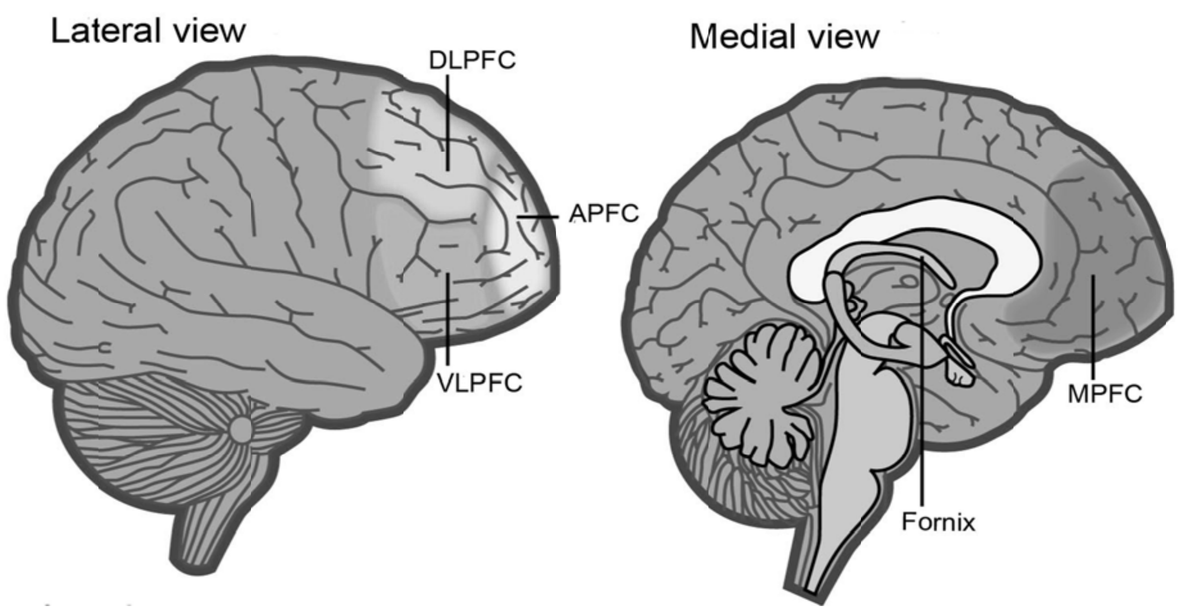

Figure 1. Major anatomical regions of the frontal lobe. DLPFC- Dorso-lateral prefrontal cortex; VLPFC-Ventro-lateral prefrontal cortex; APF-Anterior prefrontal cortex; MPFC-Medial prefrontal cortex.

The advent of MRI and fMRI brought greater spatial and temporal resolution, permitting more precise measurement and investigation. Table 1 provides brief summaries of recent imaging studies evaluating ADHD in the child and adolescent populations. As can be seen, there is convergent data suggesting dysfunction of fronto-striatal structures particularly the dorsal anterior cingulate cortex and prefrontal cortices, and strong implication of the structures of basal ganglia. This is consistent with the previously reported findings of SPECT and PET studies suggesting biological correlates of ADHD. Figure 1 provides an illustration of key anatomical regions and structures of the frontal lobe implicated in ADHD.

Table 1

Child/Adolescent Neuroimaging Studies

Study	Subjects	Type	Findings
Almeida et al. 2010	Children: 21 ADHD – med. naive, 21 age matched controls Adolescents: 20 ADHD – med. naive, 20 age matched controls	MRI—volumetric analysis of cortical thickness	ADHD subjects showed reduced cortical thickness in right frontal lobe. Specifically, regions of the right superior frontal gyrus were most reduced.
Batty et al. 2010	Children: 25 ADHD combined, 24 age matched controls	MRI—volumetric analysis of cortical thickness	ADHD subjects had lower grey matter volumes throughout the brain with the greatest decrease in frontal regions. Specifically, the inferior frontal gyrus.
Depue et al. 2010	Adolescents: ADHD combined, age matched controls	Optimized voxel-based morphometry	ADHD subjects had reduced grey matter volume in the right inferior frontal gyrus. No significant difference between groups on whole brain analysis.
Mazaheri et al. 2010	Children: 14 ADHD, 11 age matched controls	EEG—analysis of functional connectivity during a cross-modal attention task	Children with ADHD showed slower responses and atypical alpha and theta activity associated with the attention task. Results suggest functional disconnection of the frontal cortex.
Yang et al. 2010	Adolescents: 15 ADHD, 22 controls	Magnetic resonance spectroscopy	Adolescents with ADHD showed lower right prefrontal levels of creatine plus phosphocreatine suggesting neurochemical differences from control subjects.
Epstein et al. 2009	Adolescents: 10 ADHD, 14 control	fMRI-functional analysis of brain activity while performing attention task.	Adolescents with ADHD showed atypical activation in the right middle frontal gyrus at second testing suggesting developmental differences in brain activation in regions of the frontal lobe.
Jourdan et al. 2009	Children: 12 ADHD boys, 12 education, age and gender matched controls	Functional near-infrared spectroscopy analysis of performance on a Stroop task	ADHD subjects showed greater right dorsolateral prefrontal cortical oxygen consumption. Interpreted to be a compensatory reaction suggesting greater impairment of the dorsolateral prefrontal cortex.
Rubia et al. 2009	Children: 20 boys noncomorbid ADHD, 13 boys noncomorbid CD, 20 matched healthy control	fMRI – functional analysis of Simon task assessing inhibition and attention	Pure ADHD subjects showed ventrolateral prefrontal cortex dysfunction not seen in healthy control or those with CD.

Table 1 (continued)

Silk et al. 2009	Children/adolescents: 15 ADHD combined type, 15 age and intellectually matched controls	DTI- FA evaluations of the structural organization of the basal ganglia	Subjects with ADHD showed different developmental trajectories in microstructures of the caudate nucleus
McAlonan et al. 2007	Children: 28 male ADHD, 31 matched controls	MRI—Volumetric analysis. Post-hoc analysis of comorbid CD and ODD diagnoses	ADHD subjects had significant regional deficits in R frontal-pallida parietal grey matter and bilateral white matter tracks. Post-hoc comparison suggested ADHD with comorbid CD or ODD disorder had greater cerebellar and striatal volume deficits.
Ashtari et al. 2005	Children: 18 ADHD, 15 age & gender matched controls.	DTI—Analysis of white matter track diffusion	ADHD subjects had decreased FA in R supplementary motor area, R striatal, R cerebral peduncle, L middle-cerebellar peduncle and Lcerebellum.
Tamm et al. 2004	Adolescents: 10 ADHD, 9 matched Controls	fMRI—functional assessment using a go/no-go task	ADHD subjects had significantly less activation in dACC and L temporal gyrus. Decreased activation of frontal regions associated with deficits in response/ task-switching abilities.
Durston et al. 2003	Children: 7 mixed gender ADHD, 7 matched controls	fMRI—functional assessment using a go/no-go task	ADHD subjects had no activation in basal ganglia and decreased activation in VLPFC and ACC compared to controls. ADHD had greater activation in other regions located in the posterior parietal and occipital cortices.
Langleben et al. 2002	Children: 22 mixed gender ADHD, 7 age, gender & IQ matched controls	SPECT—MPH discontinuation evaluation with a go/no-go task	Higher rCBF in dACC, motor, and motor cortices following discontinuation of MPH. Suggest these areas are Implemented in ADHD positive treatment response to medication and therefore are implemented in overall pathology.
Castellanos et al. 2002	Children/adolescents: 152 mixed gender ADHD, 139 gender & age matched controls	MRI—Volumetric study evaluating a time period between 1991 to 2001	Unmedicated ADHD subjects had smaller overall brain volumes even when adjusted for covariates. Smaller overall white matter volumes were also noted. Severity of symptoms by parent/clinician report negatively correlated with frontal/ temporal grey matter, caudate and cerebellar volumes. Decreased volume remains constant across age for all areas except caudate, which increased in volume with age.
Rubia et al. 1999	Adolescents: 7 ADHD, 9 matched controls	fMRI—functional assessment using stop task and motor timing task	ADHD subjects had lower activation in R mesial prefrontal cortex during both tasks and lowered activation of the R VLPFC and L caudate during stop task compared to control subjects.

Note. ADHD = attention-deficit/hyperactivity disorder; dACC = dorsal anterior cingulate gyrus; DTI = diffusion tensor imaging; EEG = electroencephalographic; fMRI = functional magnetic resonance imaging; FA = fractional anisotropy; FOC = fronto-occipital cortex; VLPFC = ventro-lateral prefrontal cortex; R = right, L = left; CD = conduct disorder, ODD = oppositional deficit disorder.

As mentioned, to date the vast majority of imaging studies looking at ADHD disorder have been on children and adolescents. However, a problem exists in blind translation of these findings to adult populations since some of what has been found may be developmental phenomena and not chronic neurological deficits related to an underlying ADHD disorder. For instance, should the frontal and basal ganglia abnormalities seen in children and adolescents be secondary to ADHD, then similar findings should be found in adults. While the number of studies utilizing neuroimaging to evaluate ADHD in the adult population has increased, there still remains ample room for further contributions. Those that have been done to date have shown promising results and extend the child/adolescent literature linking ADHD to regions of the frontal lobe. Table 2 presents the current limited body of research on the adult ADHD population. Similar to findings in children/adolescent populations, there appears to be converging evidence implicating frontal lobe and basal ganglia deficits both in anatomical correlates (regional and globally) and functional processes thereby strengthening the hypothesis that ADHD has a neurological component. While other corroborating studies are needed, it is likely that future studies will continue to strengthen this proposed relationship.

Executive Function

Many different definitions have been proposed for executive function, although a general consensus to what executive function is has yet to be reached in the literature (Baddeley, 1986; Luria, 1980; Shallice & Burgess, 1996). While the debate continues, frequently executive function is defined as a constellation of cognitive processes that include, but are not limited to the ability to inhibit, mediate attention, plan, problem-solve, reason, regulate impulsivity, and allow for flexibility of thinking and concept formation (Eslinger, 1996; Homack, Lee, & Riccio, 2005). Baron (2004) further postulated that these higher level functions also consisted of hypothesis generation, abstract reasoning, organization, goal setting, fluency, working memory, self-monitoring, initiative, set-shifting, self-control, mental flexibility, attention, and creativity.

Table 2

Imaging Studies of Adult ADHD

Study	Subjects	Type	Findings
Almeida et al. 2010	20 ADHD – never medicated, 20 age matched controls	MRI—volumetric analysis of cortical thickness	Reduced cortical thickness in right frontal lobe. Specifically, regions of the right superior frontal gyrus were most reduced.
Cubillo et al. 2010	11 medication-naïve ADHD, 14 age matched controls	fMRI—functional evaluation using stop-go task and a task of cognitive flexibility	ADHD subjects showed reduced activation in inferior prefrontal cortex (bilaterally), caudate, and thalamus during both tasks. ADHD subjects also showed lower activation in left parietal lobe regions during task of cognitive flexibility.
Schneider et al. 2010	19 ADHD males, 17 matched controls	fMRI—functional evaluation using a continuous performance task	ADHD subjects showed impaired activation of fronto – Striatal pathways associated with attention. Specifically, reduced activation in the caudate nuclei and anterior cingulate cortex. Additionally, reduced activation found in parietal cortical networks associated with attention.
Dibbets et al. 2009	16 ADHD males, 13 matched healthy controls	fMRI – functional analysis during a modified Go/NoGo task	ADHD subjects showed less activation in the inferior frontal/orbitofrontal cortices, caudate nucleus, and nucleus accumbens.
Hesse et al. 2009	17 treatment naïve ADHD adults, 14 age matched controls	SPECT – analysis of dopamine and serotonin binding	ADHD subjects showed decreased dopaminergic reuptake function but normal serotonergic reuptake function compared to healthy control
Markris et al. 2007	24 mixed gender ADHD, 18 matched controls	MRI—Volumetric analysis of cortical thickness	ADHD subjects had decreased cortical thickness in prefrontal, lateral inferior parietal and cingulate cortices. More specifically, thinness was found in FOC, ACC and DLPFC bilaterally. Strong conclusions linking ADHD with decreased cortical integrity in areas of attention modulation and executive function.
Ernst et al. 2003	10 mixed gender ADHD, 12 age matched controls	PET —Decision making task with control task	ADHD subjects had less extensive activation in VPC, insula and DLPFC compared to control. No activation in Hippocampus, ACC and left insula compared to control group with activation in these areas.

Table 2 (continued)

Schweitzer et al. 2000	6 ADHD males, 6 matched controls	PET—Working memory task using the Paced Auditory Serial Addition Task (PASAT)	ADHD subjects produced a more diffuse pattern of rCBF compared to control on the PASAT task. General pattern consistent with decreased frontal lobe activation. Activation of diverse, alternate areas may suggest compensatory strategy employing visual imagery.
Bush et al. 1999	8 ADHD, 8 matched controls	fMRI—functional evaluation using Counting Stroop task.	ADHD subjects did not have dACC activation, control group had robust dACC activation.

Note: ADHD- attention-deficit/hyperactivity disorder; (d)ACC- (dorsal) anterior cingulate cortex; DLPFC- dorso-lateral prefrontal cortex; (f)MRI- (functional) magnetic resonance imaging; FOC- fronto-orbital cortex; PET- positron emission tomography; rCBF- regional cerebral blood flow; SPECT- single-photon emission computed tomography; VPC- ventral prefrontal cortex.

Often the term higher cognition is used interchangeably with executive function. This does not seem completely accurate, as the term executive function implies a higher-order administrative process that subsumes cognitive sub-processes and acts to integrate, moderate and regulate for the purpose of achieving an overarching goal or outcome that most often is future oriented. This is more in line with the definition provided by Welsch and Pennington (1988), who defined executive function as, "neurocognitive processes that maintain an appropriate problem solving set to attain a future goal" (p. 201). Although this definition of executive function appears generally accepted, the relationship of these processes and sub-processes is not completely understood due to their complexity (Stuss, Alexander, & Benson, 1997). Currently, therefore, executive functioning can be viewed as a consortium of multiple higher-level functions that are intimately connected, work in concert, and are difficult, if not impossible, to isolate (Delis, Kaplan, & Kramer, 2001a, Tucha et al., 2005; Welsch & Pennington, 1988).

Anatomically, a major seat of executive function is believed to involve the frontal lobes (Max et al., 2005). This association has been made due to early observations and case studies involving frontal lobe damage, with subsequent studies evaluating higher cognitive abilities in individuals with frontal lesions (Barkley, 1997; Delis et al, 2001; Faraone, et al 2000; Josdottir, Bouma, Sergeant, & Scherder, 2006; Luria, 1980; Max et al., 2005; Woods, Lovejoy, & Ball, 2002; Schweitzer et al., 2000), and more recently by function neuroimaging. In an earlier publication, Lezak (1978) described five domains of behavioral and personality difficulties commonly observed in post-head injury patients. These described symptoms are similar to characterized symptomatology of ADHD (Anderson, Anderson, & Anderson, 2006; Levin et al., 2007; Max et al., 2004; Max et al., 2005; Slomine, et al., 2005; Wassenberg, Max, Lindren, & Schatz, 2004). Frontal lobe injuries or disruptions have resulted in both observable and measurable behavioral and cognitive deficits that are often called executive dysfunction. Lezak (2004) defined this executive dysfunction as the "defective capacity for self-control, self-direction such as emotional lability or flattening, a heightening tendency towards irritability and excitability, impulsivity, erratic carelessness, rigidity, and difficulty in making shifts in attention and ongoing behavior" (p. 36).

Several measures have been created for the assessment of individual sub-processes of higher cognition. Traditionally these measures are based upon a level-of-performance analysis that consists of comparison of the individual's score to a predetermined cut-off score or provides a standardized score based upon existing normative descriptions. For example, the Trail Making Test (TMT; Battery, 1944) is believed to measure set-shifting and tracking by having an individual sequentially connect numbers and letters scattered across a page, while alternating between the two different categories. In theory, an individual with a relatively healthy brain should find the task manageable and be able to accomplish within a relatively brief time, whereas, an injured brain (frontal lobe) will find tracing and shifting between stimulus items more difficult. The TMT can be scored by both a cut-off score (Reitan & Wolfson, 1993) or a standardized score. Table 3 provides a brief description of common measures currently used to assess executive function.

Table 3

Common Neuropsychological Tests of Executive Function

Tests	Description	Higher-Cognitive Ability
Trail Making Test (TMT)	Consists of two conditions. Condition A is a sequential task using numbers. Condition B is a double sequential task that requires subject to alternate between connecting numbers in sequence with letters in sequence.	Set shifting; visual tracking
Stroop Color Word Test	Consists of three conditions, although alternative versions may have more or less. In condition 1 subject name patches of color. In condition 2 subjects read color name printed on page. In condition 3 subjects say color of ink color word is printed in.	Response inhibition, and attention
Design Fluency	Different versions exist. Subject is asked to generate as many different designs by connecting dots using straight lines.	Nonverbal fluency, organization, strategy and problem solving.
Controlled Oral Word Association Test (COWA)	Different versions exist. Subject is asked to generate as many different words that begin with specified letter. Generally consists of three different letters such as F,A,S.	Verbal fluency
Wisconsin Card Sorting Test	Subjects asked to sort cards by three possible groups, shape, color or number. After specified number of correct sorts the rule for sorting changes.	Flexibility of thinking, hypothesis generation, working memory, and attention.
Tower of London/Hanoi	Subjects manipulate blocks prearranged on pegs to construct a specific arrangement. Task must be completed following set guidelines. Rule violations can be quantified.	Problem-solving, response inhibition.

The sole use of the level of performance analysis as a measure of overall neuropsychological function has been challenged. Those in the literature that have been the most critical of this traditional approach to neuropsychological interpretation argue that an underlying assumption of the traditional approach is that all tests of higher cognitive function depend only upon that ability and do not subsume other underlying primary processes (Delis et al., 2001a). In other words, poor performance on any given measure may be related to a more basic, primary process dysfunction and not dysfunction of a higher-order process. For example, poor performance on the TMT part B is assessed by time of completion and is believed to indicate dysfunctional set-shifting and multi-task behavior. Delis and colleagues argue that it is possible a more fundamental skill (i.e., motor-impairment, sequencing or visual perception) may be the cause of the poorer performance and not difficulties with set-shifting, a higher-order function. In addition, many of the clinical measures currently used only provide a single score of function often based upon a single factor (e.g., time to complete) and fail to provide other potentially meaningful and potentially clinically rich information (e.g., number of errors committed). Rather, it is recommended that a process approach to assessment in which lower-level functions and qualitative analysis of test performance are also evaluated, thereby providing information and analysis of fundamental component skills versus higher-level cognitive functions (Cato, Delis, Abildskiv, & Bigler, 2004). This process-oriented approach, as it has been called, allows for a more comprehensive, complex, and rich qualitative evaluation that looks at both normative and ipsative comparisons, and both inter and intra-test performance.

Support for this newer process-oriented approach is increasing as evidence of its usefulness is presented in the literature. In a case study presentation, Cato et al. (2004) explored cognitive deficits in an individual with documented ventromedial prefrontal damage (VM-PFD). This cortical region was previously shown by neuropsychological and neuroanatomical studies to be involved in emotional and behavioral regulation and therefore, not believed to be associated with higher cognitive functions. A traditional level of performance analysis resulted in findings similar to those reported in the literature supporting a link between VM-PFD and emotional and behavioral changes; however, when neuropsychological testing was evaluated using a process-oriented approach, cognitive deficits were revealed. Likewise, Woods and associates (2002) found that adults with ADHD had significant group differences compared to controls on a battery of intelligence and executive function measures. When a process-oriented approach of intra-individual discrepancy analysis was used, the diagnostic sensitivity greatly increased. Woods and his colleagues suggest consideration for the use of discrepancy analysis in assessing adult ADHD.

ADHD and Executive Function

Barkley's response inhibition theory continues to gain support in the current literature, although some have been critical of this unitary mechanism approach (Songua-Barke, 2002). However, neuroanatomical and neuropsychological studies have implemented regions of the frontal lobe, particularly the anterior cingulate cortex (ACC) (Casey et al., 1997) as mediators of attention and concentration. As reported above, anatomical and functional deficits of the ACC, basal ganglia and other frontal lobe regions, including the fronto-striatal tracts, in the ADHD brain have been substantiated. Figure 2 illustrates the integrated associations of the frontal region and demonstrates how various anatomical regions are interconnected allowing for the coordinated execution of higher-order functioning. In actuality, these associations are formed through a complex integral network of cortical grey and white matter tissue that rapidly receive, process and send signals via millions of tracks and feedback loops, and form the central hub of executive functioning. Just as a compromised or insufficient highway greatly reduces the efficiency of travel, deficits to any area of this network (pathway or structure) will result in a disruption in the efficiency and efficacy of higher-order function execution.

Where ADHD was previously conceptualized as a disorder of attention and hyperactivity of a more psychological nature, current views have shifted as evidence of neurological markers of frontal lobe deficits have arisen. With repeated evidence of anatomical difference in the frontal cortical regions of those with ADHD, observed deficits on tests of cognitive function are no longer just understandable, they are expected. Indeed, the use of executive function measures in evaluating ADHD has been well substantiated (Peace, Ryan, & Tripp, 1999) and is becoming a standard practice in research on ADHD. The hope is that employing measures of executive function will increase current understanding of the disorder (Walker, Shores, Trollor, Lee, & Sachdev, 2000).

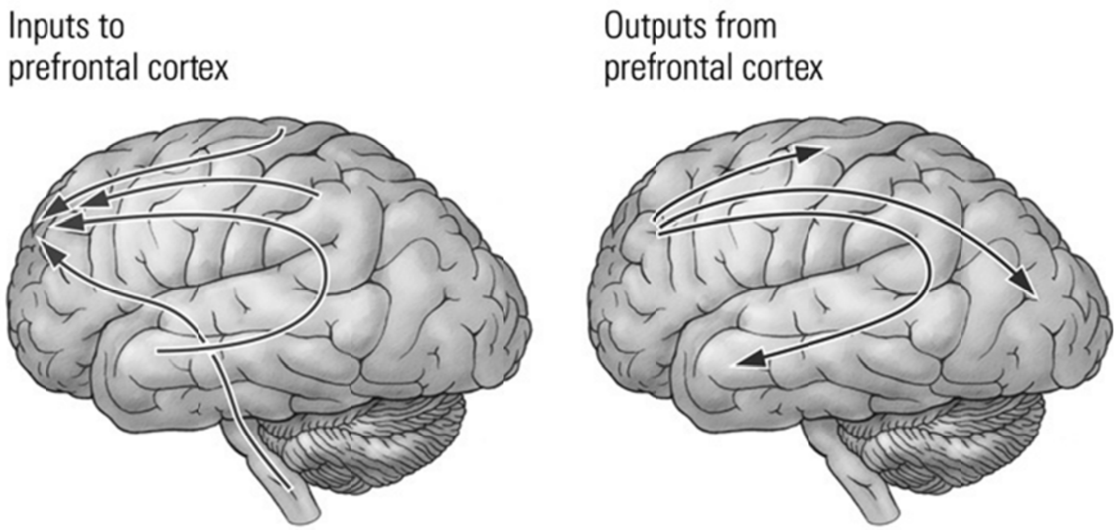

Figure 2. Interconnection of prefrontal cortical regions and other cortical regions. Adapted from B. Kolb and I. Q. Whishaw, 2000, *An Introduction to Brain and Behavior*, p. 420. Copyright 2001 Worth Publishers. Reprinted with permission.

Initial research has shown adult neuropsychological function to be similar to findings reported in the child and adolescent literature (Woods, Lovejoy, Michael, Ball, & Fals-Stewart, 2002). Table 4, originally published in Woods et al. (2002), presents a comprehensive list of studies evaluating neuropsychological function in adults. In general they found convergent data to suggest adults with ADHD had greater deficits on tasks requiring response inhibition, complex

Table 4

Summary of Studies Reporting Neuropsychological Performance of ADHD Adults.

Authors	Participants	Neuropsychological measures	Results
Woods et al. (in press)	26 ADHD 26 NC	COWA; CVLT; Stroop; TMT; WAIS±R Freedom from Distractibility.	Significant group differences (ADHD < NC) using a discrepancy analysis between intelligence and executive functions. Moderate diagnostic accuracy for the individual tests and an impairment index.
Barkley, Murphy, & Bush (2001)	104 ADHD 64 NC	KBIT; Time estimation; Time reproduction.	ADHD adults displayed significantly larger time estimations, shorter time reproductions, and more reproduction errors relative to NC.
Dinn et al. (2001)	25 ADHD 11 NC	COWA; DTT; Go/No-Go; OAT; Stroop.	Significant differences reported between ADHD subtypes, and between ADHD and NC on several dependent measures (ADHD<NC).
Epstein et al. (2001)	25 ADHD 15 Anxiety 30 NC	CPT; Stop Signal Task; VOT.	As compared to NC and patients with anxiety disorders, adults with ADHD demonstrated poorer performance on several measures of response inhibition (CPT reaction time).
Hollingsworth, McAuliffe, & Knowlton (2001)	12 ADHD 18 NC	Attentional blink task.	ADHD adults exhibited protracted attentional blink relative to NC, suggesting poor attentional shifting efficiency.
Johnson et al. (2001)	56 ADHD 38 NC	3RT; COWA; GDS; Shipley; Stroop; TMT; WCST; WMS±R.	Adults with ADHD showed poorer performance on measures of selective visual attention, memory (passage and geometric design recall), response time, and visuomotor tracking vs. NC.
Murphy et al. (2001)	105 ADHD 64 NC	CPT; COWA; KBIT; Object usage; Simon; SIT; Stroop; WAIS-III subtests.	After controlling for intelligence, significant group differences were reported for attention, inhibition, nonverbal working memory, and interference control (ADHD<NC). Gender differences emerged in the ADHD group, but there were no differences for ADHD subtype.
Rashid et al. (2001)	56 ADHD 29 LD 93 mixed	BNT; COWA; CVLT; WAIS±R; WMS±R.	No between-groups differences emerged on any of the dependent measures when controlled for IQ.

Table 4 (continued)

Authors	Participants	Neuropsychological measures	Results
Himelstein & Halperin (2000)	9 ADHD 23 NC	CPT; Competing Motor Programs Task; Target Orientation Task.	Although the results revealed similar performance between groups on sustained attention and encoding speed, ADHD adults demonstrated poorer performance on motor output/response organization.
Fujii et al. (2000)	44 ADHD	RCFT; WAIS±R.	The authors assert that IQ may be a moderating variable for RCFT copy performance among ADHD adults.
Walker et al. (2000)	30 ADHD 30 psychiatric 30 NC	Animal Fluency; COWA; CPT; Stroop; TMT; WAIS±R subtests.	Significant group differences between the ADHD and control groups on the dependent measures (ADHD<NC); no differences were identified between the ADHD and psychiatric samples.
Corbett & Stanczak (1999)	27 ADHD 15 NC	Stroop; TOAD.	ADHD adults performed significantly poorer than NC on the dependent measures. The TOAD Noise subtest correctly classified the groups 81% of the time, with minimal false negative rates.
Lovejoy et al. (1999)	26 ADHD 26 NC	COWA; CVLT; Stroop; TMT; WAIS±R Freedom from Distractibility	Significant group-differences (ADHD<NC) and adequate diagnostic classification on a battery of frontal/executive measures considered both individually and as a summary impairment index.
Schreiber et al. (1999)	18 ADHD 18 NC	ROCF	Significant between-group differences for the Neatness and Planning dependent variables within the ROCF (ADHD<NC). Logistic regression analysis was significant for Configural Accuracy, Planning, Perseveration, and Neatness.
Epstein et al. (1998)	60 ADHD 72 NC	CPT	Significant between-group differences on three CPT indices, with a strong correlation between ADHD symptoms and CPT performance. Diagnostic classification rates for the CPT were modest.
Gansler et al. (1998)	30 ADHD 10 NC	ACT; CPT; Progressive Planning Test; SIT; TMT; WCST; WMS±R.	Group differences found on TMT, CPT, and ACT (ADHD<NC). Differential executive impairment was reported for the hyperactive/impulsive and inattentive subtypes.

Table 4 (continued)

Authors	Participants	Neuropsychological measures	Results
Jenkins et al. (1998)	22 ADHD (childhood) 18 non-childhood ADHD controls	COWA; CVLT; Luria Motor/Recurring Figures; PASAT; WAIS±R; WCST	ADHD adults demonstrated significantly poorer performance on the PASAT, CVLT delayed free recall, and verbal fluency tasks. Classification rates calculated via discriminant function analysis for the battery of tests fell in an acceptable range.
Katz et al. (1998)	89 ADHD 20 depression	CPT; CVLT; Stroop; HRB; PASAT; WAIS±R; WMS±R.	Significant group differences emerged on 12 dependent variables (ADHD<NC), including Stroop, CVLT, PASAT, and WMS±R. Overall diagnostic accuracy was adequate; however, a large percentage of depressed participants were misclassified as ADHD.
Kovner et al. (1998)	19 ADHD 10 psychiatric	BFR; CPT; GLNST; LCMP; SST; WAIS±R; WRAT±R; WRMT	ADHD adults performed significantly worse than NC on the WAIS±R Digit Span Backwards and reaction time from the SST. Group classification rates derived from these variables were adequate.
Seidman et al. (1998)	64 ADHD 73 NC	CPT; CVLT; Letter Cancellation; ROCF; Stroop; WAIS; WCST; WRAT.	ADHD adults were significantly more impaired on the WRAT Arithmetic subtest, CPT omissions and late responses, as well as the CVLT total words, semantic clustering, and long-delay free-recall indices (ADHD<NC).
Weyandt et al. (1998)	21 ADHD 19 LD 24 NC	Ravens Progressive Matrices; Tower of Hanoi; TOVA; WCST.	ADHD adults demonstrated higher scores on several self-report measures of ADHD. The LD group committed a greater number of WCST errors compared to controls.
Downey et al. (1997)	41 ADHD 37 ADHD with comorbid Axis I	ACT; Category Test; CVLT; Finger Tapping; Stroop; TOVA.	Compared to a normative mean, pure ADHD adults displayed deficits on the CVLT and ACT. ADHD participants with comorbid conditions performed more poorly on the ACT and Category Test.
Epstein et al. (1997)	91 ADHD 52 nonADHD	Visual Orienting Task	ADHD adults displayed significantly longer VOT delay times, particularly at extended cue/target intervals or when an invalid cue to the left hemisphere prompted an attentional switch to the left.

Table 4 (continued)

Authors	Participants	Neuropsychological measures	Results
Roy-Byrne et al. (1997)	46 ADHD 51 poss. ADHD 46 nonADHD	CPT	Possible ADHD participants demonstrated poorer CPT index performance than either the probable ADHD or non-ADHD groups.
Taylor & Miller (1997)	211 ADHD 231 psychiatric 28 NC	Stroop; TMT; WAIS±R; WCST.	An attentional index was related to comorbidity, ADHD subtype, and group classification, but diagnostic accuracy for the ADHD and psychiatric groups was poor.
Barkley et al. (1996)	25 young ADHD 23 NC	COWA; Cookie Theft; CPT; creativity tests; Digit Span; Simon.	Young ADHD adults performed significantly more poorly on measures of working memory and demonstrated greater impairment on various CPT variables compared to NC.
Horton (1996)	11 ADHD	CT; FT; Rhythm; Speech Perception; TMT; WMS±R.	Deficits were identified on the WMS±R Logical Memory subtests and the Category Test. When demographically corrected, trends were identified for borderline scores on TMT B and CT.
Matochik et al. (1996)	21 ADHD	CPT; FDQ; GORT; WAIS±R; WCST; WRAT±R.	ADHD adults demonstrated poorer WAIS±R FD performance relative to WAIS±R VC and PO. No other significant impairments were identified.
Holdnack et al. (1995)	25 ADHD 30 NC	CPT; CVLT; TMT; WCST.	Significant differences reported on CPT reaction time, TMT Part A, and several CVLT variables ADHD<NC).
Silverstein et al. (1995)	17 ADHD 17 Tourette's 17 NC	Digit Symbol; Perceptual Speed; SOA; Stroop; TMT	ADHD subjects demonstrated poorer mental Flexibility, psychomotor speed, and test variability compared to controls. ADHD/TS patients showed worse neuropsychological impairment than TS only patients.

Table 4 (continued)

Authors	Participants	Neuropsychological measures	Results
Arcia & Gualtieri (1994)	23 ADHD 26 mCHI 25 NC	CPT; Finger Tapping; Pattern Memory and Comparison; Serial Digit Learning; WAIS±R.	Compared to NC, ADHD adults demonstrated greater variability on the CPT, poorer pattern recall, and more Serial Digit Learning errors. However, mCHI patients evidenced slower tapping speed and poorer pattern memory than the ADHD adults.
Biederman et al. (1993)	84 adult ADHD 140 child ADHD 43 ADHD rel. 248 NC	WAIS±R; WRAT±R.	ADHD adults achieved significantly lower WAIS±R FSIQ and FD scores as compared to adult NC. ADHD adults also demonstrated lower WAIS±R Block Design and higher Vocabulary, Digit Span, and FD scores when compared to children with ADHD.
Gualtieri et al. (1985)	12 ADHD 12 NC	Actometer; CPT; MFFT; WAIS±R.	ADHD adults performed significantly worse on the CPT and actometer (a physiological measure of fidgetiness) as compared to NC.
Mungas (1983)	6 ADHD 24 mixed	RAVLT; WAIS±R.	ADHD adults performed comparably to the mixed clinical reference groups on each of the dependent variables.
Hopkins et al. (1979)	70 ADHD 42 NC	Embedded Figures Test; MFFT; Stroop.	The ADHD hyperactive group displayed greater MFFT errors, longer EFT completion time, fewer EFT correct responses, longer Stroop reaction time, and a greater number of Stroop errors compared to NC.

Note. Table 4 is from "Neuropsychological Characteristics of Adults with ADHD: A Comprehensive Review of Initial Studies," by S. P. Woods, D. W. Lovejoy, and J. D. Ball, 2002, *The Clinical Neuropsychologist, 16,* p.14-17. Copyright 2002 by Taylor and Francis. Adapted with permission.

information processing speed, verbal fluency and visual attention, while discrepant findings were reported for tasks of set shifting (TMT part A and B), conceptualization, cognitive flexibility and problem solving. Poor methodology in many of the studies reported on may have accounted for some of this difference, however, more recent studies have continued to show similar findings of poor response inhibition, slower processing speed, with mixed findings for cognitive flexibility, set shifting, verbal fluency, and problem solving (Antshel et al. 2010; Boonstra, Kooij, Oosterlaan, Sergeant, & Buitelaar, 2010; Brown, 2009; Marchetta, Jurks, Krabbendam, &Jolles, 2008). Further research is needed to increase the current understanding of executive dysfunction in the ADHD population, especially in adults. The use of employing a process-oriented approach, which has shown to have added utility both clinically and in research, may provide greater understanding of and offer greater differentiation for diagnostic assessment.

Delis-Kaplan Executive Function System

The D-KEFS employs nine individual subtests designed to provide a comprehensive evaluation of higher level cognitive functioning and frontal lobe integrity (Delis, Kaplan, & Kramer, 2001b). While most of the subtests are based upon already established neuropsychological tests, many have been slightly modified to reflect recent advancements in the understanding of executive functioning (Delis et al., 2001a). The following standardized subtests compose the D-KEFS: Trail Making Test, Verbal Fluency Test, Design Fluency Test, Color-Word Interference Tests, Sorting Test, Twenty Questions Test, Word Context Test, Tower Test, and Proverb Test.

Trail Making Test. This subtest is based on the Trail Making Test originally developed by Partington in 1938, but has been modified to include 5 conditions each purported to assess a different area of functioning (Delis et al., 2001a). Condition 4 is the only condition that has been theorized to assess higher level skills; the other four conditions serve to assess and ensure that lower-level skills, such as motor speed or sequencing, are intact and therefore not confounds in the interpretation of the results for Condition 4. Condition 4 consists of a switching task that requires the examinee to connect numbers and letters in sequence while alternating back and forth between the numbers and letters. Executive functions believed to be important for the successful completion are: cognitive flexibility and inhibition of perseverative responding.

Verbal Fluency Test. This subtest requires an individual to randomly generate words based upon given parameters such as words beginning with the letter *F*, and is based upon the original FAS verbal fluency test. The D-KEFS builds upon this by including a categorical fluency test, such as generating boys names and animal names, and a switching task where the respondent alternates between giving the name of a fruit and a piece of furniture (Delis et al., 2001a), The believed areas of executive function assessed are cognitive flexibility, response inhibition, and verbal fluency.

Design Fluency Test. This subtest, similar in nature to the verbal fluency test, evaluates nonverbal fluency by asking the examinee to generate as many unique designs as possible in a given time period by drawing four lines that connect an array of dots displayed in boxes (Delis et al., 2001a). The examinee is presented with rules that must be applied to each design, and credit is not given for any rule violations. There are three different conditions, each with its own set of rules. Nonverbal fluency, response inhibition and cognitive flexibility are the features of executive function believe to be assessed by this subtest.

Color-Word Interference Test. Based upon the original Stroop-Color Word Test, this subtest is generally believed to be one of the more challenging tasks for those with ADHD (Rapport et al., 2001). Similarly to the Trail Making Test, this subtest consists of four individual test conditions. Conditions 1 and 2 serve as lower-level assessments of color naming and word reading. Condition 3 introduces a distracter by displaying the names of colors across the page printed in the ink of a different color. For example, the word *red* would be printed in blue ink. The subject then has to say the name of the ink color while inhibiting responses of saying the word. Condition 4 builds upon Condition 3 by introducing a switching response. Here again, color word names are printed in a different ink color, but random words are outlined with a black box. The examinee is told to name the color of the ink unless the word is within a box, at which point they are instructed to read the word, and not name the color of the ink. Executive functions employed in this subtest are response inhibition and cognitive flexibility.

Sorting Test. This test is based upon an earlier measure shown to be very sensitive to multiple executive function deficits in patients with frontal lobe lesions (Delis et al., 2001a). Examinees are presented with six different cards varying in perceptual features and printed words, and then asked to sort the cards into two groups of three according to as many different categorical ways as possible, such as by shape, color, etc. (Delis et al., 2001a). Several areas of executive functioning are assessed with this subtest including initiation of problem-solving behavior, verbal and nonverbal concept-formation skills, transfer of concepts into action, and flexibility of thinking.

Twenty Questions Test. In this subtest the examinee is shown a page with 30 common objects displayed. They are instructed to try and guess which of the objects the examiner is thinking of by asking as few *yes* or *no* questions as they can (Delis et al., 2001a). Each of the 30 objects can be broken down into various categories and subcategories for example, living things: animals, which can aid the examinee in correctly guessing the item in as few guesses as possible. While this subtest was based upon a similar test developed by Mosher and Hornsby (1966), several modifications were made to the version found in the D-KEFS. Key areas of executive functioning tapped by this subtest include the ability to recognize categories and subcategories, abstract question formation, and efficiency in problem-solving.

Tower Test. This test has its roots in several earlier tests such as the Towers of Hanoi, London, and Toronto, but extensions in score ranges were made by including both easier and more difficult items so as to improve the overall psychometrics of the test (Delis et al., 2001a). Here examines are presented with *n* number of discs of varying sizes in a specific array and are asked to arrange the discs on the board so that they match the stimulus picture presented, and to do so in as few moves as possible. There are a number of rules the examinee has to follow, such as moving only one ring at a time and never placing a larger ring on top of a smaller ring. In each subsequent part the number of rings and the complexity of the moves required to successfully complete the task increases. This test taps into spatial planning, rule learning, inhibition of impulsive responding, inhibition of perseverative responding, and establishing and maintaining instructional set (Delis et al., 2001a).

Proverb Test. This subtest was originally developed in 1988 by the originators of the D-KEFS and consists of 8 sayings that are presented to the examinee, who is asked to offer an interpretation into the meaning of the saying (Delis et al., 2001a). Interpretation of this test includes insights into the examinee’s verbal abstraction skills.

Word-Context Test. The original Word Context Test, developed by Edith Kaplan and Heinz Werner, is believed to assess the acquisition of word meaning in children (Delis et al., 2001). Previous research established that performance on this measure required several higher-level cognitive abilities. The examinee is shown a pseudo-word and tries to discover its meaning by interpreting a series of clues that begin generally and then narrow down in precision. A higher score is one that requires as few clues as possible to solve the mystery. Executive functions tapped by this subtest include: verbal modality and assessing skills such as deductive reasoning, integration of multiple bits of information, hypothesis testing, and flexibility of thinking.

The D-KEFS subtests can be administered individually or in concert to provide more comprehensive evaluation of frontal lobe integrity. Table 5 presents current research demonstrating regions of frontal lobe dysfunction based upon individual D-KEFS subtests. Studies evaluating anatomical correlates for all D-KEFS subtests could not be found. In these instances, tests the D-KEFS subtests were based upon were substituted.

Purpose of Present Study

The purpose of the current study was to further examine the relationship between executive functioning and adults diagnosed with ADHD. If impaired executive functioning is observed, the implications for disrupted frontal lobe function will add to the literature implicating frontal lobe dysfunction in ADHD. While executive functioning has been well researched in children and adolescents with ADHD, there still remains a paucity of research looking at these functions in the adult population (Tannock, 1998). Earlier studies have varied in numerous ways in methodology, diagnostic criteria, and results. None of the studies to date have employed as comprehensive a battery of frontal lobe functioning as the D-KEFS, and few have employed a process-oriented analysis. Inasmuch as no study could be found that examined the relationship between executive functioning in adults with ADHD using the D-KEFS, a comprehensive tool for assessing the complex multifactorial domains of frontal lobe functioning (Homack et al., 2005), it seemed only logical that adults with ADHD should be evaluated using this test.

Table 5

Anatomical Correlates of D-KEFS Subtests and Related Measures

Subtest	Study	Findings
Trail Making Test	Stuss et al. 2001	Error analysis was most revealing. All subjects with 1 or more errors had frontal lobe lesions. Subjects with greater number of errors had lesions in the dorsolateral frontal areas.
	McDonald et al. 2005	Subjects with frontal lobe epilepsy were more impaired on a set-shifting task compared to subjects with temporal lobe epilepsy. Suggesting frontal lobe involvement for set-shifting processes.
	Yochim et al. 2007	Subjects with LPC lesions performed worse on Conditions 2, 3 and 5 and were slower on Condition 4. LPC lesion subjects also committed more errors on Condition 4.
Verbal Fluency Test	Levin et al. 2001	Interaction of age with site of lesion detected as adolescents with left frontal lesions had greater deficits on verbal fluency task.
	Phelps et al. 1997	Activation of prefrontal cortex, left inferior frontal and anterior cingulate cortex on task of verbal fluency.
	Cuenod et al. 1995	Activation of left premotor cortex and left dorsolateral prefrontal cortex on task of verbal fluency.
Design Fluency Test	Kramer et al. 2007	Found in a sample of 101 subjects after controlling for working memory, only left and right frontal lobes correlated with nonverbal set-shifting task.
Color-Word Interference Test	Stuss et al. 2001	Frontal lobe lesions produced significant impairment. Left dorsolateral frontal lobe damage resulted in increased errors and slowness of response for color naming. Bilateral superior medial frontal lobe damage was associated with increased errors and slowness in response time for incongruent condition.
	Carter et al. 1998	In an fMRI study of a different task that incorporated some of the demands of the Stroop, both lateral frontal regions appeared recruited for monitoring and detecting errors and both cingulate regions appeared activated for sustaining attention during interference.
Sorting Test	Parmenter et al. 2007	Poorer performance on Sorting Test correlated with brain atrophy in MS subjects even after controlling for depression. Significant difference in number of sorts, description score, and repeated sorts.
Twenty Questions Test	Marshall et al. 2003	Subjects that had sustained close head injuries and had diverse cerebral damage ask few constraint-seeking questions and had poorer question-asking efficiency. Total number of questions asked did not differ.
	Goldstein et al. 1991	Subjects with severe close head injury required more questions and used poor strategy for solving task compared to control.
Tower Test	Levin et al. 1994	Found correlation between head injury and deficits on Tower of London Test. Larger frontal lesions in the orbital, dorsolateral and white matter of the frontal lobes predicted greater cognitive impairment.

Research Hypothesis

According to the null hypothesis (H_0) there will be no relationship between diagnostic classification and the domain of executive function. More specifically, poorer individual performance on measures of higher-cognitive function will not be associated with a diagnosis of ADHD. This is to say that the two are independent of each other. This relationship is represented as H_0: $\rho = 0$. Alternatively, should the null hypothesis be rejected and the alternative hypothesis (H_A: $\rho \neq 0$) accepted, then empirically one could state with more confidence that there is a linear relationship suggesting some level of effect between these variables. Based upon the literature, the following hypotheses were explored.

Hypothesis I. Adults with ADHD will perform more poorly as a group overall on primary level-of-performance scale scores from the DKEFS. Furthermore, it is anticipated that most notable differences will be seen in the domains of set-shifting, fluency, and response inhibition, and that the subtests that theoretically tap into these domains will exhibit the greatest level of significant difference. Specifically, the following subtests will exhibit the greatest degree of difference: Trail Making Test: Condition 4 (set-shifting), Verbal Fluency Test: Conditions 1, 2 and 3 (fluency), Design Fluency: Conditions 2 and 3 (fluency), Color-Word Interference Test: Conditions 3 and 4 (set-shifting and response inhibition), and Tower Test (response inhibition).

Hypothesis II. As a group the ADHD subjects will perform significantly different from control subjects on process-oriented analysis. Specifically it is expected that subjects with ADHD will make more errors on Condition 4 of the TMT, have greater set-loss errors on both verbal and design fluency tasks, and make more errors on Condition 3 and 4 of the CWIT.

Objective. The current study evaluated the effectiveness of using the DKEFS as a diagnostic tool for evaluating ADHD in adult male populations. As is stated in the first hypothesis, it is expected that ADHD subjects will perform significantly different from matched control subjects. It is hypothesized that because ADHD subjects have been shown to have similar deviations in neuroanatomy, specifically with regions associated with mediation of attention and concentration, they will perform similarly to each other on DKEFS items and that this similarity may suggest a diagnostic pattern. This pattern is expected to exist for both level-of-performance and process-oriented analysis.

Method

Participants

The ADHD sample group consisted of thirty-seven right-handed adult males between the ages of 22 and 53 with an average age of 27.4 (*SD* = 6.8). Diagnostically, the combined subtype comprised 54.1% of the sample (*n* = 20) with 21.6% (*n* = 8) having the impulsive-hyperactive subtype, and the remaining 24.3% (*n* = 9) having the inattentive subtype. Forty-three percent (n = 16) of those in the experimental group had a comorbid diagnosis. Ethnicity representations included Caucasian (*n* = 32, 86.5%), Hispanic (*n* = 3, 8.1%) and Asian (*n* = 2, 5.4%). Participant education ranged from 12 to 18 years (*M* = 14.3, *SD* = 1.2), and the average IQ was 118.2 (*SD* = 8.38). All participants reported being currently enrolled in local universities, gainfully employed or both.

Participants in the control group were matched as closely as possible to the experimental group based on age and education status, and consisted of 37 right-handed adult males ranging in age from 18 to 45 (M = 24.1, *SD* = 5.9). Thirty-seven percent (*n* = 14) had a diagnosis other than ADHD (e.g., mood disturbance, anxiety, etc) while the remaining 23 reported no current or prior history of mental health concerns. Ethnic representations among the control group included Caucasian (*n* = 30, 81.1%), Hispanic (*n* =3, 8.1%), Asian (*n* = 2, 5.4%) and other (*n* = 2, 5.4%). Education ranged from 12 to 16 years (*M* = 13.8, *SD* = 1.2) and the average IQ was 113.7 (*SD* = 9.43). Participants in the control group all reported current enrollment in local universities, gainful employment or both.

Participants in both groups were made up of convenience samples from the Utah County area and recruited primarily from a private outpatient mental health clinic, University Accessibility Center (UAC) or the university general population. Participants in the experimental group were previously diagnosed with ADHD by clinicians at either the private outpatient clinic or UAC. The participating clinics provided individuals with a diagnosis of ADHD a flyer outlining the current study. Contact information was provided on the flyer and individuals with questions or interest in participating were directed to contact the principle investigator. Exclusion criteria were set prior to the start of the study and included: self-reported history of any type of TBI, including concussion, loss of consciousness (LOC) or trauma requiring medical attention, history of illicit drug use, or current use of pharmacological agents for treatment of ADHD.

Currently, there are no definitive guidelines regarding pharmacologically treated ADHD subjects discontinuing medication for the purpose of obtaining baseline testing. While some debate continues about the benefits of stimulant-mediated performance on neuropsychological evaluation, there is increasing evidence that active treatment of stimulant medication, as is commonly used for the treatment of ADHD, enhances performance on cognitive tests (Pietrzak, Mollica, Maruff, & Snyder, 2006), whereby artificially masking cognitive and executive dysfunction associated with the disorder. In addition, there is no clear evidence that discontinuation of stimulant medication causes any sort of withdrawal state or exacerbation of symptoms (Greenhill, Findling, & Swanson, 2002) that might compromise performance. Therefore, if a participant in the current study was willing to discontinue their medication for the purpse of testing and did not meet any other exclusion criteria, they were permitted to participate. Swanson and Volkow (2002) report a fairly brief half-life for stimulants used in ADHD treatment (3-4 hours to return to baseline symptomatology). Therefore, subjects in the current study were asked to abstain from their medication for a minimum of 24 hours prior to their scheduled testing session, with the average participant going 2 - 3 days (abstaining over the weekend and testing on a Monday afternoon). This is line with the recommendations of Ernst et al. (2003). Of the experimental group only 16 (43%) subjects were currently taking medication and therefore requested to discontinue short-term for testing, while the other 21 (57%) were medication naïve because they had recently been diagnosed with ADHD and yet to begin any medication, or were not currently utilizing medication for symptom management. None of the participants reported a history of head trauma, LOC, concussion, or substance abuse resulting in exclusion from the study; one participant preferred not to discontinue his medication and was therefore excused from the current study.

As indicated previously, participants in the ADHD group were selected for their preexisting ADHD diagnosis. While the current sample population was used because of its convenience, both referring mental health agencies were selected to participate based upon their rigorous screening and assessment procedures that provided increased confidence that those diagnosed with ADHD actually meet diagnostic criteria. Both agencies utilized a multifaceted approach that included use of standardized assessment measures of attention (e.g., Conners' Continuous Performance Test), self-report questionnaires (e.g., Conners' Adult ADHD Rating

Scale or the Wender Utah Rating Scale), and a thorough clinical interview by a licensed clinical psychologist or board-certified psychiatrist specializing in working with ADHD. In addition each site indicated that, where possible, corroborating information was also considered in making the final ADHD diagnosis.

Participants in the control group were recruited via flyer and/or referral from the outpatient clinic and university classrooms. Participation in either group was completely voluntary and no monetary compensation or feedback on test performance was offered. A few of the control participants were eligible to receive concomitant course credit for participating in research conducted on campus and in such cases, the appropriate notification was provided to their instructor.

Procedure

The current study was approved by the Brigham Young University IRB committee. Before participants were admitted into the study, each received and was required to provide signed informed consent. Participants then completed a demographics questionnaire, cognitive testing and the DKEFS. Testing was conducted at either the outpatient clinic or in a private office on campus by one of two fourth-year doctoral students trained in clinical psychology and neuropsychological test administration. At the beginning of each testing session, each participant was reminded of the conditions of their consent. Testing was typically completed in one session and occurred primarily in the late afternoon, with most sessions lasting between 2-3 hours. Regular breaks were offered. While participants were informed of their right to discontinue testing at any time during the session, all participants completed the full battery of measures and no participant gave indication of any excessive discomfort or negative outcome as a result of participation in the study. Upon completion, tasks were scored by the principle investigator and later double checked to assure accuracy. Completed scores were then entered into a spreadsheet, checked for errors and analyzed using SPSS.

Measures

Delis-Kaplan Executive Functioning System (DKEFS). A detailed description of the DKEFS has been provided above; therefore the following description will only include reported psychometrics. Reliability and validity for the DKEFS are listed by age group for each subtest and reported in the technical manual that accompanies the test battery (Delis et al., 2001b). There is some variance reported in the manual for individual subtests' reliability and validity (ranging from the low to high range), with some in the literature being more critical of these claims suggesting that more work is needed to establish the reliability and validity of the DKEFS itself. In their critical review, Homack et al. (2005) point out that the psychometric properties, specifically split-half reliability, as reported in the technical manual vary across subtest, conditions within subtests, and age groups. Specifically, low to moderate split-half reliability coefficients were reported for Verbal Fluency Test – Categorical Switching Total Correct (.37-.68) and Twenty Questions Test – Total Weighted Achievement (.10 – .51). Moderate to high reliabilities were reported for Verbal Fluency Test – Letter Fluency Condition (.68 – .90, Color-Word Interference Test (.62 – .86), Sorting Test—Sort Recognition (.62 – .81), Twenty Questions – Initial Abstraction (.72 – .87), and Proverb Test (.68 – .80). All other subtests fell within the moderate to good range. Perhaps the greatest strength of the battery is that each of the nine subtests has been co-normed on a large and relatively representative national sample with ages ranging from 8 to 89 years.

Wechsler Abbreviated Scale of Intelligence (WASI). The WASI is an abbreviated adaptation of the well-established Wechsler Adult Intelligence Scale series (WAIS) originally designed as a screener to briefly assess cognitive functioning in individuals between the ages of 6 and 89 years (Psychological Corporation, 1999). The entire battery consists of four subtests (two per verbal and nonverbal domains respectively) that are intended to capture both fluid and crystallized intelligence within the domains of verbal and nonverbal reasoning abilities (Stano, 2004). In addition, the WASI provides an estimate of a Full Scale Intelligence Quotient comparable to the Full Scale IQ obtained on the WAIS with a mean of 100 and a standard deviation of 15. The verbal index consists of the Vocabulary and Similarity subtests, while Block Design and Matrix Reasoning make up the nonverbal domain. The entire four-subtest form takes an estimated 30 minutes to administer and is favorable for use in research because of this brevity and adequate psychometric properties. The test boasts excellent reliability coefficients as reported by the manual ranging from .84 to .98 for adults (Psychological Corporation, 1999). Furthermore, the battery has been shown to have excellent convergent reliability (.86) with other brief measures of cognitive assessment, especially when employing the Full Scale IQ score (Canivez, Konold, Collins, & Wilson, 2009).

Statistical Approach

All data points were entered and re-entered for verification into SPSS and an overall multivariate analysis of variance (MANOVA) was run on all dependent executive function variables with group, ADHD vs. Non-ADHD control, as the between-subjects factor. With so many dependent variables included in the final analysis and because of their theoretical relationship under the broad domain of executive function, the use of MANOVA seemed not only appropriate but necessary to reduce the likelihood of committing a Type I error (Spector, 1981). Finally, individual dependent variables were compared for significance. Significance was set at the $p \leq .05$ level with effect size considerations based upon Cohen's recommendations: small (.15 – .39), medium (.40 – .74), large (.75 – 1.09) and very large (≥ 1.10) (Cohen, 1988).

Given that subjects in the present study were not matched for IQ, some may question the reasoning for using MANOVA instead of MANCOVA, with IQ treated as the regressor of no interest. Indeed, a longstanding debate continues within the field about whether statistical adjustment for potentially influencing, yet uncontrolled variables is a mathematically and theoretically sound practice. Certainly research in the behavioral sciences is limited by what variables investigator can control or ethically should attempt to control. It seems only natural and perhaps desirable that employing a formulaic way to artificially adjust for preexisting differences would be warmly welcomed. However, the debate about use of covariate adjustment in the behavioral sciences continues, and this is particularly true for the present study: should IQ be covaried in studies of ADHD? The rationale in the current study to forgo covariate analysis is based upon the recommendations of Lord (1967, 1969) and those of Dennis et al. (2009). In his early publication on the issue, Lord utilized a simple illustration to demonstrate how disparate conclusions can be drawn from the same data set depending on which statistical analysis one employs. Lord concludes that while adjusting for actual preexisting differences may be desirable, there is not a logical or statistical formula that can validly adjust for these unwanted differences. Regarding the relationship of IQ and ADHD Dennis et al. (2009) expressed this view:

> Attempting to control for IQ differences when examining specific neuropsychological deficits like executive function in ADHD (Barkley et al., 2001; Murphy et al., 2001) is methodologically tenuous (Frazier et al., 2004) because decrements in overall ability are a feature of ADHD (and of any neurodevelopmental disorder defined in terms of

cognitive-behavioral deficits), making statistical "control" impossible (Campbell & Kenny, 1999, pp. 338-339).

Results

Box's *M* is a statistic that provides information on the homogeneity of the variance-covariance matrix used in multivariate analysis. Therefore, when this statistic is significant ($p \leq .01$) the null hypothesis is rejected and significant difference between covariance is assumed. It is preferable that when evaluating data points the assumption of homogeneity not be violated, although, as Tabachnick and Fidell (2001) point out, when utilizing multivariate analysis (i.e., MANOVA) and sample sizes are equal across cells, MANOVA is remarkably robust and resistant to the effects of this violation. For the current study Box's *M* was found to be significant ($p < .001$). Given equal sample sizes and the recommendations of Tabachnick and Fidell (2001) proceeding with the multivariate analysis is acceptable. Levene's test of homogeneity of variance across dependent variables was non-significant in all cases except: Trail Making Test: Condition 5 ($p < .01$); Trail Making Test: Total Errors ($p < .01$); Color-Word Interference Test: Condition 2 ($p < .01$); and Proverb Test: Achievement ($p < .01$). As indicated, MANOVA is considered a robust test against violations of the assumptions of homogeneity; however, individual examination of group differences on these items may not be valid.

Group Comparisons

The overall MANOVA for all dependent executive function measures showed a large effect for ADHD diagnosis (Wilks' $\lambda = .244$, $F(32,41) = 3.98$, $p < .001$, $\eta^2 = .76$). The two groups were statistically equal in domains of education, $t(72) = -1.88$, $p = .06$, and age, $t(72) = -1.79$, $p = .08$. However, the ADHD group had a higher IQ ($M = 118.2$) than the Non-ADHD control group (M = 113.7), $t(72) = -2.16$, $p = .03$. Group means, standard deviations and effect sizes are shown in Table 6.

Trail Making Test. For the Trail Making Test group differences were found for the level-of-performance measures of Condition 4 (Letter-Number Switching task) and Condition 5 (Motor Speed Task). In both cases, members in the experimental group were slower to complete the specified task. The former is believed to assess higher-order abilities of cognitive flexibility and response inhibition, while the latter measures visual-motor speed, believed to be a lower-order function. In addition, group difference was found when comparing the total number of errors made for the switching task, a process-oriented measure. The ADHD group, as a whole, scored lower on this measurement suggesting they were more prone to making errors than their control counterparts.

Verbal Fluency Test. No group difference immerged on any of the level-of-performance or process-oriented scores. This measure assesses phonemic and categorical fluency along with inhibition and cognitive flexibility.

Design Fluency Test. Only Condition 2 (Empty Dots Only) showed a notable group difference. The ADHD group as a whole created fewer correct designs when the novel task of inhibition was added to the instruction set.

Color-Word Interference Test. No group differences emerged on measures assessing lower-order functioning (i.e., color naming or word reading) but when task difficulty was increased by adding higher-order functions of response inhibition and cognitive flexibility, those with a diagnosis of ADHD had slower time to completion scores. Surprisingly, performance on process-oriented approach measures (i.e., total error commission) showed no group differences.

Table 6

Group differences among DKEFS scores

DKEFS	Control *n* = 37		ADHD *n* = 37			
	M	*SD*	*M*	*SD*	*F*	Cohen's *d*
Trail Making Test: Condition 1	10.16	2.52	10.19	2.63	.002	.01
Trail Making Test: Condition 2	11.19	2.04	11.57	1.64	.773	.21
Trail Making Test: Condition 3	12.14	1.77	12.00	1.61	.118	.08
Trail Making Test: Condition 4	11.41	1.66	10.43	2.5	3.89*	.46
T rail Making Test: Condition 5	12.62	0.64	11.92	1.75	5.24*	.54
Trail Making Test: Total Errors	11.54	1.15	10.70	1.53	7.14**	.63
Verbal Fluency Test: Letter Fluency	12.38	2.60	12.05	3.13	.236	.12
Verbal Fluency Test: Category Fluency	13.22	3.04	13.05	3.28	.049	.03
Verbal Fluency Test: Category Switching Total	12.03	2.53	12.11	2.50	.019	.05
Verbal Fluency Test: Category Switching Accuracy	12.38	2.48	12.19	2.27	.117	.08
Verbal Fluency: Setloss Errors	11.46	1.48	11.43	1.71	.005	.02
Verbal Fluency: Repetition Errors	9.76	2.57	9.84	2.48	.019	.03
Design Fluency: Condition 1	11.22	2.57	11.19	2.72	.002	.01
Design Fluency: Condition 2	12.62	2.63	11.11	2.66	6.051**	.58
Design Fluency: Condition 3	12.51	2.98	12.32	3.14	.071	.06
Design Fluency: Setloss Errors	11.38	2.47	11.73	1.97	.459	.16
Design Fluency: Repetition Errors	11.76	1.89	11.97	1.24	.339	.13
Color-Word Interference Test: Condition 1	10.70	2.21	10.46	2.43	.203	.10
Color-Word Interference Test: Condition 2	11.70	1.63	10.81	3.40	2.064	.17
Color-Word Interference Test: Condition 3	11.24	2.39	9.78	3.34	4.673*	.25
Color-Word Interference Test: Condition 4	11.30	2.69	9.73	2.34	5.138*	.53

$*p \leq .05$; $**p \leq .01$.

Table 6. (continued)

DKEFS	Control $n = 37$		ADHD $n = 37$			
	M	*SD*	*M*	*SD*	*F*	Cohen's *d*
Color-Word Interference Test: Condition 3 Total Errors	10.49	2.26	9.76	2.77	1.542	.29
Color-Word Interference Test: Condition 4 Total Errors	10.92	1.51	10.76	1.96	.158	.09
Sorting Test: Confirmed Correct	11.08	1.93	12.14	2.18	4.851*	.52
Sorting Test: Free Sort Description	10.70	2.23	12.08	2.65	5.852*	.57
Sorting Test: Recognition Description	9.76	2.61	11.62	2.61	9.386**	.72
Twenty Questions: Abstraction	11.78	3.27	11.86	1.49	.014	.03
Twenty Questions: Total Questions	11.43	1.64	10.76	2.03	2.473	.37
Twenty Questions: Achievement	11.62	2.02	11.22	2.39	.620	.18
Word Context Test: Total Correct	10.95	1.81	12.57	2.01	13.32**	.86
Tower Test: Achievement	11.54	3.25	11.73	2.21	.085	.07
Proverb Test: Achievement	11.84	1.83	11.46	1.15	1.134	.25

Note. Mean scores are Scaled Scores that have been converted based upon the individual's raw data and age as prescribed by the DKEFS Technical Manual. In all cases, a higher score indicates more favorable performance.
$*p \leq .05$; $**p \leq .01$

That is to say, those with ADHD required longer times to complete the more difficult task but were able to do so without committing more errors than the control group.

Sorting Test. Participants in the ADHD group performed better on all level-of-performance and process-oriented domains assessed suggesting more efficient verbal/non-verbal concept-formation.

Twenty Questions Test. No group differences emerged on level-of-performance or process-oriented scores. This measure assesses categorical identification, abstraction, and working memory.

Word Context Test. For the Word Context Test only the level-of-performance score was used, which showed a significant group effect. Those with ADHD performed better than their non-ADHD control counterparts.

Tower Test. On the level-of-performance score, a measure of spatial planning, abstract problem-solving and inhibition of impulsive responding, no significant group differences emerged. This task is believed to require spatial planning, inhibition and problem solving abilities.

Proverb Test. There were no group differences on this measure of verbal abstraction. This suggests no difference between groups for verbal abstraction and knowledge of social conventions.

Post hoc review of the data revealed several diametric outliers of IQ scores in both the experimental and control groups. In the ADHD sample no subjects had a Full Scale IQ lower than 100 while five subjects in the control group fell in the mid 90 range. Conversely, several subjects in the experimental group were found to have IQ scores higher than 128 while only one in the control group was above this level. To assess the impact of these outliers, subjects were matched for IQ with the outliers removed, and the data were reanalyzed ($n = 28$ for each group). As before, no group differences were found for age or education. However, the group means for IQ were now similar (ADHD $M = 114.71$; Control $M = 114.32$, $p = .80$). The interaction between group and executive function was still very robust, Wilks' $\lambda = .016$, $F(32,22) = 41.58$, $p < .001$, $\eta^2 = .98$. Group means, standard deviations and effect sizes for the adjusted sample are shown in Table 7. In general, removal of outliers resulted in more robust findings suggesting poorer performance on multiple DKEFS measures in the study group compared to the control.

Table 7

Group differences among DKEFS scores with outliers removed

DKEFS	Control *n* = 28		ADHD *n* = 28			
	M	*SD*	*M*	*SD*	*F*	Cohen's *d*
Trail Making Test: Condition 1	10.07	2.75	9.71	2.77	3.62	.13
Trail Making Test: Condition 2	11.00	2.31	11.25	1.71	.104	.12
Trail Making Test: Condition 3	12.11	1.99	12.11	1.77	.294	.00
Trail Making Test: Condition 4	11.39	1.71	9.79	2.41	4.77**	.76
T rail Making Test: Condition 5	12.57	.690	11.57	1.84	3.58*	.72
Trail Making Test: Total Errors	11.61	1.10	10.71	1.68	3.25*	.63
Verbal Fluency Test: Letter Fluency	12.43	2.87	11.32	3.08	1.32	.37
Verbal Fluency Test: Category Fluency	12.79	2.5	12.86	3.46	1.49	.02
Verbal Fluency Test: Category Switching Total	12.21	2.88	11.61	2.31	9.54**	.23
Verbal Fluency Test: Category Switching Accuracy	12.50	2.82	11.71	1.99	8.82**	.32
Verbal Fluency: Setloss Errors	11.50	1.62	11.32	1.66	.084	.11
Verbal Fluency: Repetition Errors	9.79	2.67	9.82	2.42	.021	.01
Design Fluency: Condition 1	11.29	2.67	10.29	1.41	1.52	.47
Design Fluency: Condition 2	12.32	2.79	10.64	2.18	3.17*	.67
Design Fluency: Condition 3	12.25	2.96	11.21	2.46	1.31	.38
Design Fluency: Setloss Errors	11.21	2.71	11.93	2.12	2.06	.30
Design Fluency: Repetition Errors	11.54	2.06	12.29	1.12	5.62	.45
Color-Word Interference Test: Condition 1	10.36	2.41	10.5	2.03	.425	.06
Color-Word Interference Test: Condition 2	11.71	1.86	10.39	3.66	1.49	.45
Color-Word Interference Test: Condition 3	10.79	2.39	9.00	3.36	3.45*	.61
Color-Word Interference Test: Condition 4	10.93	2.78	9.14	3.49	2.37	.57
Color-Word Interference Test: Condition 3 Total Errors	10.14	2.40	9.61	2.9	2.20	.20

Table 7 (continued)

DKEFS	Control *n* = 37		ADHD *n* = 37			
	M	*SD*	*M*	*SD*	*F*	*Cohen's d*
Color-Word Interference Test: Condition 4 Total Errors	10.93	1.70	10.57	2.22	6.37*	.18
Sorting Test: Confirmed Correct	11.57	1.84	11.57	2.13	0.30	.00
Sorting Test: Free Sort Description	11.14	2.26	11.43	2.60	0.31	.12
Sorting Test: Recognition Description	10.11	2.28	10.82	2.37	2.97	.31
Twenty Questions: Abstraction	12.68	3.24	11.79	2.13	1.95	.32
Twenty Questions: Total Questions	11.36	1.70	10.39	2.02	3.34*	.52
Twenty Questions: Achievement	11.79	1.99	10.61	2.04	6.79**	.59
Word Context Test: Total Correct	11.11	1.73	12.11	1.93	5.11**	.55
Tower Test: Achievement	11.68	3.10	11.46	1.93	4.19*	.13
Proverb Test: Achievement	11.68	1.98	11.32	1.19	5.02**	.22

Note. Mean scores are Scaled Scores that have been converted based upon the individual's raw data and age as prescribed by the DKEFS Technical Manual. In all cases, a higher score indicates more favorable performance. *$p \leq .05$; **$p \leq .01$.

Discussion

Summary of Findings

The current study evaluated performance on tasks of executive functioning as measured by the Delis-Kaplan Executive Functioning System in adult males with a diagnosis of ADHD by comparing their performance to a sample of culturally similar, non-ADHD community constituents. The study originally proposed to investigate three main questions: (1) do adult males with ADHD show a difference in performance on overall measures of executive function as measured by the DKEFS, (2) what differences, if any, emerge between the two groups on both level of performance and process-oriented approaches; and (3) does a specific clinical profile observable across DKEFS measures emerge and if so, is there diagnostic utility.

The current findings are consistent with an increasing body of evidence suggesting ADHD is a neurologically based disorder involving frontal lobe difficulties (Almeida et al., 2010; Cubillo et al., 2010; Woods et al., 2002). Using multivariate analysis, group comparisons found overall significant group differences on neuropsychological measures of executive functioning. As has been previously discussed, the frontal lobes are widely accepted to be the anatomical seat of executive function we conclude, therefore that, overall impairment in executive control, as seen in this sample of adult males with ADHD, is likely reflective of disruption to or under-development of those underlying anatomical correlates responsible for organization and execution of higher-order functions.

Several group differences were found on specific tasks of higher-order functioning and between process-oriented scores that are mediated, in part, by self-monitoring and response inhibition. While many of the observed differences were anticipated, others were found that were not predicted by the original hypothesis. As expected, the ADHD group took longer to complete condition 4 from the Trail Making Test, which requires response inhibition, and made more errors overall, but unexpectedly they also took longer to complete condition 5, a measure of simple motor speed, motor control, and visual scanning. Interestingly, post hoc review found that a small sub-group of individuals in the ADHD group (24%) made at least one error on this task compared to 5% in the control group. Most often the error occurred when the individual failed to inhibit a response to connect two adjacent circles instead of following the prescribed line to a more distant target circle. Figure 3 shows the response form of an individual from the study group with the described error type delineated.

While previous reviews have suggested impaired fluency (Woods et al., 2001), the current study's findings are more consistent with the findings of Desjardins, Scherzer, Braun,

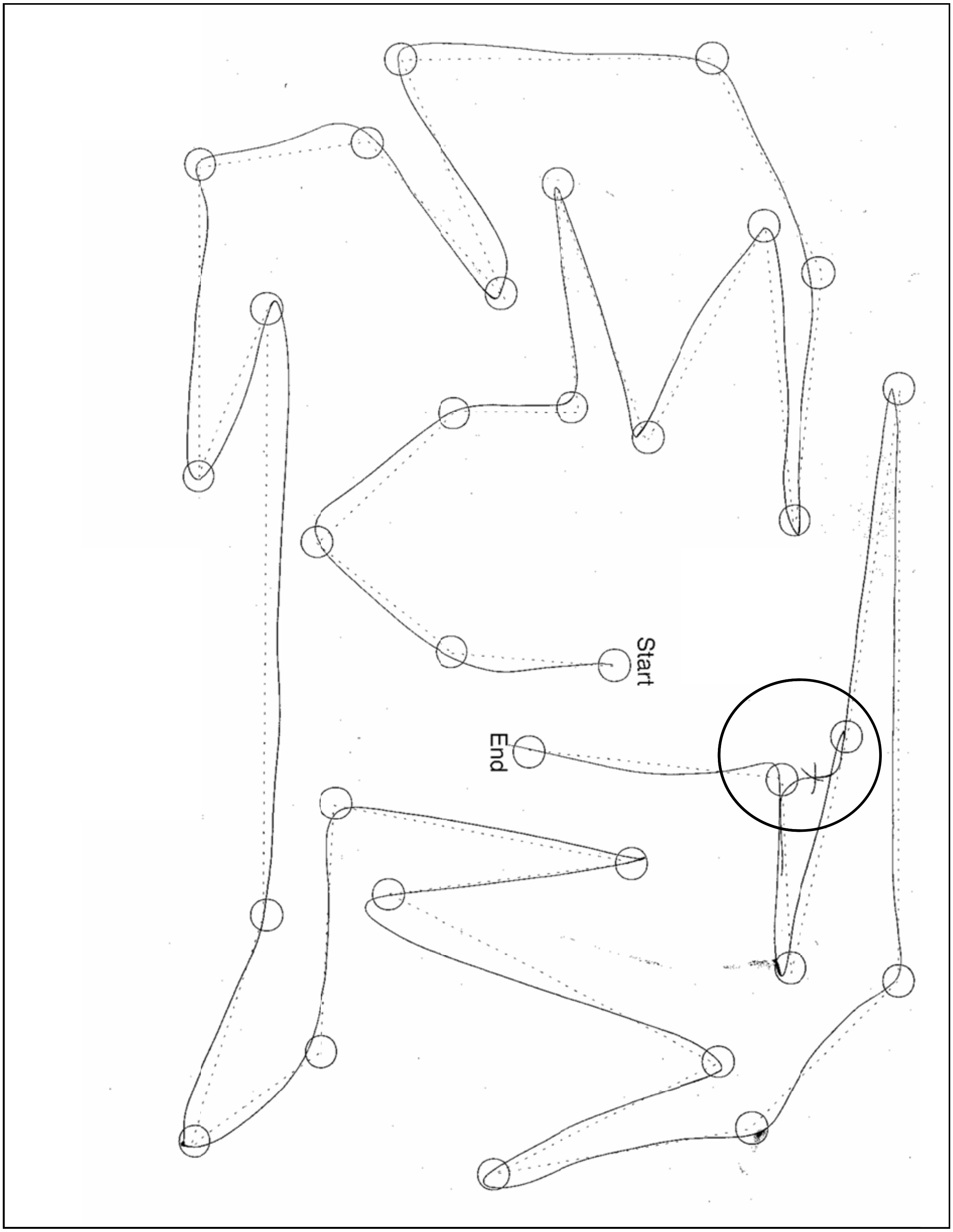

Figure 3. Sample of common sequencing error committed on the TMT Condition 5 in ADHD sample. The large circle identifies the site of the error present in 24 percent (n = 9) of the experimental group.

Gldbout, and Poissant (2010); that is, no measureable difference on tasks of pure phonologic and categorical verbal fluency, even with outliers removed. However, with the added difficulty of having to alternate between generating words from differing categories (cognitive flexibility) those with ADHD were less capable than their IQ-matched peers.

Surprisingly, only Condition 2 of the Design Fluency Test was found to have a significant difference between the two groups with the study group generating fewer designs overall. Although both Condition 2 and 3 theoretically involve inhibition, Condition 3 introduces greater demand with the addition of a switching component and it was predicted that those with ADHD would be more impeded on this measure as well. This was not found to be the case. Rather, no difference emerged between the two groups. It is possible that, while inhibition plays a role in successful management of this task, there are other factors that also must be considered. Latzman and Markon (2010) conducted a factor analysis of the DKEFS and found three main factors emerge: Conceptual Flexibility, Monitoring and Inhibition. While the Design Fluency subtest loaded most directly onto Inhibition, this loading was relatively weak compared to the other subtests that also loaded on this factor (e.g.,Color-Word Interference Test). Therefore, there must be some other factor mediating performance.

Achievement across all three conditions of the Design Fluency Test is measured by total number of novel designs. A fundamental issue relating to good performance, then, is the use of a strong strategy that allows the individual to rapidly construct multiple designs while limiting repetition errors. Indeed, an approach in which the individual makes small sequential changes to their design facilitates both the need for rapid design output while minimizing the amount of errors committed. Such a process also reduces the need for effortful error monitoring as long as the individual follows their strategy's prescribed sequential change pattern. Therefore, adequate performance, in part, likely becomes a measure of organization, creativity, and fluid reasoning. It is probable that while those with ADHD struggled with the added inhibition element of Condition 2, that on the third trial of this overall fluency exercise (Condition 3) they had developed a useful strategy that reduced the overall difficulty of the task. This explanation is further supported by a quick comparison of the mean differences between the original experimental group and the adjusted, IQ-matched sample (see table 6 and 7). When the effects of fluid intelligence were reduced the difference between the two group means became larger, although it still did not reach significant levels.

Consistent with the predictions of hypothesis I, those with ADHD showed slower time-to-completion on both Condition 3 and 4 of the Color-Word Interference Test, which are analogs of the original Stroop Color and Word Test. Furthermore, as predicted, performance on measures of lower-level functioning (reading/color naming) did not differ between groups with or without outliers removed. Poorer performance in individuals with ADHD on the similar Stroop measures has long been established and the current project continues to add to that base (Antshel et al., 2010). This study's second hypothesis predicted that in addition to taking longer to complete, that those with ADHD would commit more inhibition related errors. The current results are mixed. Based upon the overall sample, no significant difference in error commission was found. However, when subjects were matched for IQ and outliers removed those in the ADHD group were found to commit more errors on Condition 4 (inhibition and flexibility) whereas the time-to-completion score was now similar. Why this reverse was observed for Condition 4 when outliers were removed is not fully known. It may be that within the overall ADHD group there were subgroups that differed on their focused approach to the task. As part of the instruction set, the examinee is told to work as quickly as possible without making any mistakes. If an individual became fixated on rapidly responding they would be less likely to inhibit the pre-attentive, incorrect response and make more errors. Whereas, if more emphasis is placed on accuracy of responding the individual would make fewer errors but at the overall cost of time (Delis et al., 2001a). It is possible that within the current experimental group that there were those that focused primarily on accuracy over speed while others focused more on sacrificing accuracy for speed. This details why a process-oriented approach to clinical interpretation of scores is so valuable because if one only paid attention to the level-of-performance score clinically rich data could be lost (Cato et al, 2004).

On all three measures of the Sorting Test that were examined, the ADHD group outperformed the non-ADHD sample. However, in post hoc analysis when the samples were adjusted to match for IQ these significances disappeared. One possible explanation for this observation may be in the IQ difference between the two groups. Davies (2005) generally found moderate to strong positive correlations between full scale IQ and performance across DKEFS measures including Sorting Recognition. However, a significant correlation was not found for the Sorting Confirmed Sorts or Sorting Description measure. In that study correlation between IQ and DKEFS scores were made both overall and broken down into nine different age groups. It should be noted that the overall sample size was large ($n = 197$), but when the data were broken down by individual age groups correlation between IQ and the Sorting Test could not be calculated due to an insufficient number of Sorting Test administrations. While the Sorting Test was included in the IQ-DKEFS correlations for the entire population, no total number of Sorting Test administrations was reported, and therefore, the study may have lacked sufficient power to detect the correlation. An alternative explanation is that in this particular sample of individuals with ADHD those underlying functions contributing to the overall level of performance on the

Sorting Test are not only spared, but perhaps well-developed compared to their non-clinical peers.

Significance between scores on measures of the Twenty Questions Test was not found with the overall sample; however, post hoc review found that in the IQ-matched group significance emerged, suggesting that the ADHD sample, overall, may have utilized less efficient strategies such as random guessing. Intellectual advantage in the non-adjusted sample is a probable explanation for why no difference was found in the original experimental sample.

In both the original analysis and the post hoc adjusted analysis, performance on the Word Context Test was found to be in the favor of the experimental group. That is, the control group performed poorer on this measure. There is no definitive explanation for this finding. However, it is plausible that as a group, those with ADHD inherently have at their disposal some underlying skill set that provided them an advantage on this measure. Indeed, much of the research to date addressing ADHD focuses on a deficits model and fails to explore, or at least consider that while on whole the symptom cluster of ADHD suggests impaired executive functioning, there may be a set of adaptive abilities that are well developed and provide these individuals with a functional advantage. Such a claim is intriguing but well beyond the scope and power of this study; however, the author of this work recommends that while ADHD will likely continued to be conceptualized as an executive disorder, future research should explore the notion that as a developmental cluster, ADHD may have some selective advantage.

Contrary to predictions, no group difference was found on the Tower Test for the overall sample. A mild significance was found on post hoc exploration when outliers were removed, however, the effect size was small (.13) and of no clinical utility. Existing research utilizing similar assessment measures (i.e., Tower of Hanoi, Tower of London) has shown equivocal results (Riccio, Wolfe, Romine, Davis, & Sullivan, 2004) but the current study anticipated that the increase range of difficulty offered by the Tower Test in the DKEFS battery might offer more discriminate clarity (Delis et al., 2001a). While in the IQ-matched group the experimental group showed slightly poorer performance, it cannot be said without equivocation that deficits of response inhibition greatly impact performance on this measure. Rather, further research is required to more completely identify the role, if any, that deficits of response inhibition, as experienced by those with an organic based attention deficit, have on performance on this particular measure. It is very plausible that while response inhibition can impact an individual's tower performance that other performance factors (i.e., problem-solving or spatial planning) are more salient demands.

Similarly to the results on the Tower Test, no group difference emerged on the Proverb Test. However, when matched for IQ, individuals with ADHD were found to have the disadvantage. Again this was not clinically significant and may reflect actual impairments mediated by the underlying defective substrates implemented in ADHD or may reflect some other unknown variable unique to the current study's population. Further studies will need to explore this further.

While statistical differences were found between those with ADHD and healthy controls, the findings were not as robust as those reported elsewhere in the literature (Antshel et al., 2010; Biederman et al, 2009; Schwartz & Verhaeghen, 2008), and this was surprising. A couple of explanations are possible here. First, the current experimental group may be more an exception than a rule as it relates to cognitive abilities. There is strong evidence to suggest that a representative ADHD sample will have below average scores on measures of intelligence (Bridgett & Walker, 2006; Dennis et al., 2009.) and are often significantly lower than control groups. This was not the current case. Rather, the ADHD subjects were found to have higher overall scores on intellectual measures. Executive function and cognitive capacity are not mutually independent but share significant overlap and thereby directly influence one another (Tillman, Bohlin, Sorensen, & Lundervold, 2008) and current measures fail to purely isolate one functions of one domain or the other (Davis, 2005). For example, many measures used to assess cognitive capacity require more executive level functions (e.g., planning, reasoning, etc.) Therefore, a true executive dysfunction will also impact scores on intellectual tests and may artificially deflate them. Based upon this notion, the current experimental group's intellectual scores may not accurate reflect the group's true capacity which actually may be higher. Conversely, higher cognitive capacity would buffer measured impairment on the current tests of executive function. Wherein one would gain more insight into the degree of individual impairment by utilizing a intra-individual comparison of abilities rather than a between group comparison. This is in line with the findings of Brown (2009).

Another potential explanation for the findings in this study relates to the criticism often levied against objective measures of executive function. An increasing number of researchers are critical that the current objective measures of executive function lack good ecological validity. That is to say, these measure do not accurately capture actual deficits as they are experienced by the individual in the real-world milieu (Chaytor, Schmitter-Edgecombe, & Burr, 2006; Gioia & Isquith, 2004; Manchester, Priestley, & Jackson, 2004). The critics assert that the relatively structured and low-stimulus environment created during objective assessments of this nature likely provides the individual an environmentally mediated compensatory advantage. Furthermore, the game-like format of many of these measures exposes the individual to a task that is novel and very brief. It is likely that most found the assessment interesting and easier to attend to. This is supported in that a large percentage of participants in both groups expressed intrigue and enjoyment in completing the assessment measures. The issue, then, becomes a issue of what the individual is capable of (maximum cognitive capacity) versus what the individual typically experience in their day-to-day interactions (typicality). Truly, the current way of assessment administration favors maximum performance and gives an estimate of what the individual is capable on the "best of days" but poorly reflects what the individual experiences regularly.

A final explanation for the current studies results are related to the third objective of this study, which was to explore the diagnostic utility of the DKEFS in identifying ADHD in the clinical population. This objective relates to the applicability in real-world clinical practice. In practice the main interest is clinical meaningfulness which is often defined by an individual's score in relationship to the overall population. Often, diagnostic significance is set at a point equivalent to 1.5 standard deviations or greater from the mean, although more liberal allowances would start at only a single standard deviation. While there is strong evidence that the ADHD group performed poorer on a constellation of executive functioning tasks, there was not a single measure that approached clinically meaningful levels. That is to say, was at least a standard deviation below the mean of the normative sample (scaled score ≤ 7). Therefore, a clear ADHD profile based upon level-of-performance scores did not emerge with this population. In addition, analysis of the process-oriented scores yielded similar findings: no clear pattern. This is consistent with the findings of Wodka et al. (2008) who found no clear evidence of deficits on DKEFS process measures in a large sample of children with ADHD other than a few mild gender x ADHD subtype interactions.

In developing assessment measures emphasis is placed on issues of sensitivity, the ability of a measure to detect the variable of interest, and specificity, the ability of the measure to discriminate unrelated variables from the variable of interest. While the DKEFS has shown adequate sensitive to deficits in executive function, and arguably even mildly captured that in the current study, it does not appear to be sensitive enough to be diagnostically useful with the current study's population. It must be emphasized here that this conclusion can only be related to the current study's population and should not be inappropriately generalized to other populations (e.g., ADHD in lower cognitive functioning individuals). Future studies will need to explore the clinical utility of the DKEFS with ADHD and other "minimal brain" deficit disorders. What may emerge, rather, is that the DKEFS is better suited for detecting more significant deficits of frontal lobe function as seen in other populations (e.g., TBI, dementia, etc).

Despite the lack of a clear clinical profile of significance, some trends did emerge that are worth noting. Consistent with the current theories and research of ADHD, the current ADHD sample had greater problems on tasks placing demands on inhibition. Therefore, it could be expected that an individual with ADHD will show some difficulty on select subtests placing greater demand on inhibition such as TMT: Condition 4, Design Fluency: Condition 2 and CWIT: Conditions 3 and 4. Regarding the process-oriented measures, there is some indication here that those with ADHD may commit more errors on TMT: Condition 4 and CWIT: Condition 4, although further research is needed to explore the relationship between ADHD and error commission rates on the DKEFS.

Finally, while not directly addressed in the DKEFS manual, the errors committed by examinees while completing Condition 5 of the TMT was interesting and may prove to have diagnostic importance. As indicated previously, those in the experimental group had a higher frequency of committing an inhibition error on this visual-motor integration task. If future research with the ADHD population shows similar trends, then such an error may become diagnostically important.

Limitations

The current investigation is limited in some specific ways. Despite effort to recruit as diverse and representative sample as possible, the author was limited to a convenience sample that consisted largely of volunteer college-aged Caucasian males from the Utah County area. In addition, to the inherent limitations imposed by studies utilizing a self-selecting population, the current sample population was further limited in that the group came from a unique but homogenous culture. While this is a limitation, it was also strength as all the participants had no history of alcohol or controlled substance use thereby minimizing the influence of substance-abuse confounds. Caution is warranted in inferring about findings beyond those listed.

The current study also failed to directly control for an effects associated with comorbidity. There is clear evidence that other clinical presentations such as mood disturbances, anxiety, overt psychotic processes or concerns of developmental delay can disrupt executive functioning in adolescent and adult populations (Beaudreau, & O'Hara, 2009; Clark, Iversen, & Goodwin, 2001; Degl'Innocenti, Agren, & Backman, 1998; Greenwood, Morris, Sigmundsson, Landau, & Wykes, 2008; Merchan-Naranjo et al., 2010; O'Hearn, Asato, Ordaz, & Luna, 2008). However, this is not seen as a significant limitation given that similar disorders (i.e., mood or anxiety disorders) were included in the control population as well.

Another limitation is that the current study did not have enough participants to evaluate the possible interaction profile between ADHD subtype classification and performance on measures of executive function. There is not a clear standard in the current research as whether or not subtype classification (hyperactive, inattentive, combined) should be considered in conducting research on ADHD in the adult population. In part, this may be a result of the observed disproportion of ADHD subtype diagnosis seen in the adult population. Estimates suggest 56-62% have the combined type, 31-37% have the inattentive type, and 2-7% have the hyperactive type, with over 90% presenting with the chief complaint of inattentive symptoms (Millstein, Wilen, Biederman, & Spencer, 1997; Wilen et al., 2009). However, the current study showed some within group variability for those with ADHD and this may reflect actual differences in performance between subtypes or may represent some other unknown characteristic of the sample group. It is possible that treating the study sample as homogenous, when it appears in fact to be heterogeneous, may have confounded the current results and limited the effect size of the results.

Another limitation of the current study was the way study participants were diagnosed and subsequently recruited. The diagnosis of ADHD was given prior to recruitment and dependent upon clinicians at two independent sites. The current study did not control for the standardization of diagnostic procedures nor could it completely ensure the rigorous quality of those diagnostic assessments and therefore is limited by the assumption that each participant with ADHD was accurately classified. In addition, in most cases those in the study group were diagnosed as adults, and there is some concerns related to the dependence on retrospective assessment, as current DSM-IV-TR diagnositic criteria require symptom manifestation occur at a very early age. However, there is support in the literature supporting retrospective diagnostic practices as being adequately reliable (Kessler et al., 2005), and as detailed in a previous section, both referring clinics utilized rigorous assessment methods to insure an accurate diagnosis. Future research should address this concern by employing either a primary or, at the minimum, a secondary diagnostic verification screen of some type (i.e., objective measure, such as the Wender Utah Rating Scale, and a clinical interview).

A final limitation of the current study is the characteristics of the study group. The current ADHD sample may not accurately reflect the overall population of adults with ADHD. There is evidence of mean differences between IQ scores in those with ADHD and aged matched controls, with the ADHD group typically scoring lower (Bridgett & Walker, 2006; Dennis et al., 2009; Kuntsi et al., 2004). However, in the current study, the converse was found with the ADHD sample showing, on average, higher overall scores on measures of intellectual functioning. Therefore, the current group likely represents an upper extreme (1.5 - 2 standard deviations above the general ADHD population). Unfortunately the way the current study was designed biased for this outcome. It is important to remember that the current group was made up of primarily university students that were referred for participation in the study following a recent diagnosis of ADHD. For the majority of these individuals this was the first time they had been diagnosed and only sought an assessment after finding they no longer could easily manage the organizational demands and academic rigor that university life requires. While each of these individuals likely displayed ADHD symptoms at much younger ages, their higher intellectual abilities provided a buffer preserving them from academic failure or adaptive dysfunction earlier in life and allowed them to evade diagnostic identification. Therefore, it is possible that the findings in this study may not be generalizable to more typical presentations of ADHD.

Recommendations for Future Research

The current debate over the clinical presentation of adult ADHD is likely to continue for some time. However, based upon the current results a few recommendations are made to guide future research. First, given the overall homogenous nature of the population used in this study, it is recommended that future research try to incorporate a more representative sample of ethnic and cultural backgrounds. Whereas the current study only considered a male population, future research will want to incorporate a stratified gender sample as well.

There exist differing views on the clinical manifestations of ADHD subtypes with some reporting little to no difference between cognitive functioning and ADHD subtype (Murphy, Barkley, & Bush, 2001) while others report adequate difference (Dinn, Robbins, & Harris, 2001; Gansler et al., 1998). The current study did not have an adequate sample to explore potential differences between diagnostic subtypes and as discussed, this was a limitation. The variability in variance found in the current study may reflect underlying differences in neuropathophysiological substrates associated with each clinical subtype or may have been a function of some unique attribute of the study group. It will be important given the equivocal findings in the current literature and the variability seen in the present study that future research on this topic, especially studies of adult ADHD using the DKEFS, explore any potential subtype-performance interactions by including large enough samples of differentiated subtypes. This is consistent with the recommendations of Wood et al. (2001). Furthermore, future studies should look at the interaction of ADHD subtypes on both DKEFS level-of-performance and process-oriented measures. Given the within-group variability seen in the current study, additional insights of underlying substrate impairment may be found should differences emerge on various process-oriented tasks of the DKEFS.

While an overall correlation between ADHD and executive dysfunction is being established in the literature, there still remain variable findings and opinions with some suggesting a unitary underlying mechanism (Barkley, 1997; Boonstra et al., 2010; Sergent, 2000) and others calling for a multi-component explanation (Schacher et al., 2004; Sonuga-Barke, 2002). The current study attempted to add clarity to this debate, and is believed to have done so. However, as Wood et al. (2001) detailed in their meta-analysis, a portion of the discrepant results is likely due to a lack of methodological robustness. Inattention and hyperactivity, while key symptoms of ADHD, are not diagnositically exclusive and are seen in a variety of disorders including, mood disturbance, PTSD, autism, substance-abuse, psychosis, and cognitive disorders associated with acquired brain injury, to name a few. Therefore, future research should utilize appropriate and rigorous methods to ensure accurate diagnostic labeling. In situations where there is diagnostic uncertainty, the researcher should be conservative and exclude those subjects. As more pure ADHD samples are studied, the overall cognitive profile, if one does indeed exist, may become clearer. Furthermore, if such a clear profile does not immerge, this may provide insight that the underlying mechanism of ADHD is not necessarily unitary but multidimensional.

As discussed in a previous section Dennis et al. (2009) argue that attempts to control for IQ in populations of neurodevelopmental disorders (i.e., ADHD) is unfounded, if not poor practice. These recommendations are based upon understanding that neurodevelopmental disorders (i.e., ADHD) directly impact IQ functioning resulting in overall lower means on intellectual measures. The use of IQ-matched subjects in post hoc analysis in the current study is in line with the recommendations of Dennis and her colleagues, who suggest that when a group is not representative of the overall population of the group (like the current study population) then manipulation may be appropriate. When the current group was matched for IQ more robust findings emerged. Moreover, it is likely that if a more representative ADHD sample (lower intellectual functioning) were used the findings of the current study may have been significantly different. Therefore, future work will want to ensure a more representative sample relative to IQ. The results could then be more generalizable and perhaps more clinically relevant.

Conclusions

Recent theories of Attention-Deficit/Hyperactivity Disorder have classified it as more a neurodevelopmental disorder with disruption of the executive system of cognitive functioning. Although a growing body of research links ADHD to impaired performance on many measures of executive function mention, no study to date has examined the relationship between adults with ADHD and performance on the Delis-Kaplan Executive Function System, a battery of executive function measures. The current study utilized a small sample of adult males with ADHD to evaluate overall executive functioning, and individual evaluation of level-of performance, and process oriented measures from the DKEFS. Results found a significant correlation between ADHD diagnosis and executive function, despite an overall intellectual advantage in the ADHD group. Process oriented measures yielded more information when IQ was matched and suggested those with ADHD were more impulsive and prone to making errors on tasks of inhibition in addition to requiring more time to complete.

Despite these findings, results were not as robust as initially expected. Reasons for this may have included underlying functional differences in diagnostic subtypes, disproportionately high intellectual abilities in the study sample, lower ecological validity of measures of executive function as a result of a highly structured and novel situation, and/or poor sensitivity of the measure for this population. These findings should lead researcher in future work to explore interaction of diagnostic subtypes and utilize a more representative sample to explore profile analysis of the DKEFS. While the current study did not find clear evidence of an ADHD profile for diagnostic utility, this is not to say that future research will not demonstrate such a profile of impairment. The current study does, however, provide some recommendations for clinical utility, and supports the claims of Delis et al. (2001) that the DKEFS has decent construct validity making it adequately sensitive to executive function. The findings from this dissertation offer a modest contribution to the field and further support the building evidence that ADHD is a neurodevelopmental disorder with fundamental deficits in overall executive functioning.

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