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Central Executive Functioning and Electrodermal Levels in Adults with and without Clinically Significant Attention-Deficit/ Hyperactivity Symptoms

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To the Graduate Council:

I am submitting herewith a thesis written by Megan Carl entitled "Central Executive Functioning and Electrodermal Levels in Adults with and without Clinically Significant Attention-Deficit/ Hyperactivity Symptoms." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Psychology.

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Central Executive Functioning and Electrodermal Levels in Adults with and without Clinically Significant Attention-Deficit/Hyperactivity Symptoms

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Abstract

Adults diagnosed with Attention-Deficit/Hyperactivity Disorder (ADHD) demonstrate impaired performance on central executive (CE) functioning tasks (Alderson, Hudec, Patros, & Kasper, 2013a; Boonstra, Oosterlaan, Sergeant, & Buitelaar, 2005; Nigg et al., 2005) and underarousal of the sympathetic nervous system as measured by the electrodermal levels (EDLs) during resting state paradigms (Hermens et al., 2004). CE functioning and arousal are linked in three theoretical models of ADHD. No study to date has examined the degree to which EDLs (arousal) are related to ADHD-related cognitive impairments. This study examined (1) performance associated with central executive functioning and (2) EDLs while increasing CE processing demands and controlling for storage capacity in adults with and without clinically significant ADHD symptoms. All participants performed significantly better on the condition with lowest CE processing demands (e.g., the short-term memory condition) relative to the conditions with greater CE processing demands (e.g., working memory conditions; all $ps \leq .003$).

While no significant between-group differences in EDLs were observed, the control group demonstrated a significant decrease in EDLs during tasks that required greater CE processing demands (e.g., working memory conditions) relative to tasks that required less CE processing demands (e.g., short-term memory conditions), whereas participants with clinically significant ADHD symptoms demonstrated little modulation of EDLs across all conditions (all $ps > .05$).

Keywords: ADHD, central executive functioning, electrodermal levels

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List of Abbreviations

ADHD	Attention-Deficit/Hyperactivity Disorder
Ag/AgCl	Silver/Silver Chloride
ASRS	Adult ADHD Self-Report Scale
BAARS-IV Current	Barkley Adult ADHD Rating Scale-IV Self-Report: Current Symptoms
BAARS-IV Child	Barkley Adult ADHD Rating Scale-IV Self-Report: Childhood Symptoms
BAI	Beck Anxiety Inventory
BDI-II	Beck Depression Inventory-2
CE	Central Executive
DSM-III-R	Diagnostic and Statistical Manual of Mental Disorders, 3rd Ed., Revised
DSM-IV-TR	Diagnostic and Statistical Manual of Mental Disorders, 4th Ed., Text Revision
EDA	Electrodermal Activity
EDLs	Electrodermal Levels
ES	Effect Size
GPAs	Grade Point Averages
IRB	Institutional Review Board
LS	Level setting
MINI	Mini International Neuropsychiatric Inventory
PH	Phonological
STM	Short-Term Memory
VS	Visuo-Spatial
WASI-2	Wechsler Abbreviated Scales of Intelligence, Second Edition
WM	Working Memory

1. Introduction

1.1 Adult Attention-Deficit/Hyperactivity Disorder

Core symptoms of Attention-Deficit/Hyperactivity Disorder (ADHD) include age-inappropriate inattention and hyperactivity/impulsivity levels occurring prior to age 12 (American Psychiatric Association, 2013). Since the late 1960s, research emerging supports the continued manifestation of ADHD symptoms into adulthood (Barkley, 2006a). The American Psychiatric Association, however, established ADHD as a valid diagnosis for adults in the DSM-III (American Psychiatric Association, 1980; McGough & Barkley, 2004), with an estimated prevalence rate of 4.5-5 percent in adults in the United States (Barkley, 2006b; Castellanos, Sonuga-Barke, Milham, & Tannock, 2006; Faraone et al., 2000; Kessler et al., 2006; McGough & Barkley, 2004; Wilens, 2004; Willcutt, 2012). Studies estimate that about 15-42 percent of individuals diagnosed with ADHD during childhood demonstrate moderate to severe symptoms of inattention and/or hyperactivity/impulsivity (Baddeley, 2012; Barkley, 2006a; Hill & Schoener, 1996) during adulthood.

Although overt hyperactivity/impulsivity ratings in adults are reduced, relative to childhood hyperactivity/impulsivity ratings, inattention symptoms remain problematic (Alderson, Hudec, Patros, & Kasper, 2013a; American Psychiatric Association, 2013; Biederman, Mick, & Faraone, 2000; Young & Gudjonsson, 2008). Whereas substance use (American Psychiatric Association, 1980; Barkley, 1997; Faraone et al., 2000; McGough & Barkley, 2004), risky sexual behavior, and traffic violations (Barkley, 2006a; 2006b; Barkley, Fischer, Smallish, & Fletcher, 2006; Castellanos et al., 2006; Faraone et al., 2000; Kessler et al., 2006; McGough & Barkley, 2004; Sergeant, Oosterlaan, & Van Der Meer, 1999; Wilens, 2004; Willcutt, 2012) are related to hyperactivity/impulsivity symptoms in adults, academic

impairments, occupational impairments, cognitive problems and lower educational attainment (Barkley, 1997; 2006a; Gropper & Tannock, 2009; Sergeant et al., 1999) are related to inattentive symptoms in adults.

1.2 Arousal and ADHD

In addition to the core symptoms of inattention and hyperactivity/impulsivity, individuals diagnosed with ADHD exhibit unique patterns of physiological arousal. Early researchers hypothesized a link between hyperactive/impulsive symptoms of ADHD and physiological overarousal (Hastings & Barkley, 1978). However, research has established that children and adults with ADHD symptoms are underaroused physiologically despite overt hyperactivity/impulsivity relative to children and adults without ADHD symptoms (Hermens et al., 2004; Satterfield & Dawson, 1971). Individuals with ADHD symptoms demonstrated physiological underarousal, specifically through electrodermal activity (EDA), which quantifies activity of the sympathetic nervous system by measuring the reduction in electrical resistance of the skin in response to stimuli (Miller & Long, 2008). EDA is further quantified by measuring gradual changes in activity over time or electrodermal levels (EDLs) (Fowels, 2008).

Considerable research has focused on assessing EDLs in children and adolescents diagnosed with ADHD. Previous studies have examined EDLs in relation to attention/vigilance, or simple learning tasks in children and adolescents with ADHD. EDLs in children and adolescents with ADHD are found to be significantly lower than children and adolescents without ADHD during resting paradigms (Crowell et al., 2006; Hermens, Kohn, Clarke, Gordon, & Williams, 2005; Iaboni, Douglas, & Ditto, 1997; Lazzaro et al., 1999; Satterfield & Dawson, 1971; Shibagaki, Yamanaka, & Furuya, 1993) tone discrimination paradigms (Hermens et al., 2005; Satterfield & Dawson, 1971; Sheehan et al., 1998; Shibagaki et al., 1993), and reward-

extinction paradigms (Iaboni et al., 1997). In addition, adolescents aged 16-18 diagnosed with ADHD exhibited lower EDLs throughout the Test of Variable Attention, a computerized measure of sustained attention and impulsivity (Wilde, 2007). With the exception of resting paradigms, all of the previously mentioned tasks require attention to simple stimuli (e.g. tones or lights) by the participants.

Traditionally, EDLs in adults diagnosed with ADHD have been assessed using resting paradigms. For example, Hermens and colleagues compared resting EDLs in 35 adults diagnosed with ADHD and 35 adults without ADHD (Hermens et al., 2004). In this study, the participants were asked to sit quietly in a chair with their eyes closed for a two-minute rest period while physiological data were recorded. Adults in the ADHD group demonstrated significantly lower EDLs than individuals without ADHD suggesting lower physiological arousal (Hermens et al., 2004). While adults with ADHD may have a similar arousal profile, no study to date has examined the degree to which EDLs are associated with ADHD-related cognitive impairments

1.3 Working Memory and ADHD

In addition to physiological underarousal, individuals diagnosed with ADHD present with impaired performance on various neuropsychological tasks, particularly measures of executive functioning. Barkley defines executive functioning as "self-directed actions needed to choose goals and to create, enact, and sustain actions toward those goals, or […] self-regulation to achieve goals" (Barkley, 2012, p.66). In the context of completing cognitive tasks, executive functioning is the ability to solve problems, direct attention, and engage working memory (WM). The largest and most consistent between-group effect sizes in executive functioning deficits (ranging from .20-.89) in individuals diagnosed with ADHD are associated with WM

impairments (Alderson, Hudec, Patros, & Kasper, 2013a; Alderson, Kasper, Hudec, & Patros, 2013b; Boonstra et al., 2005).

WM is the multi-component system that not only stores phonological (PH) and visuo-spatial (VS) information in immediate awareness and processes the information, but also is able to simultaneously manipulate the information in order to solve problems, complete tasks or send the information to long-term storage (Baddeley, 2012). Baddeley's Multi-Component WM model (2012) consists of the central executive (CE), which serves as the control system for the other two components, the PH and VS storage and rehearsal loops. The CE has four primary functions: 1) focusing attention on a task, 2) dividing attention between two or more tasks, 3) switching attention between tasks, and 4) interacting with long term memory stores as needed to complete task (Baddeley, 2012; see Figure 1). The CE is crucial to everyday problem solving tasks from simple arithmetic to abstract reasoning. Impairments in CE functioning can include problems listening, understanding directions, and inhibiting impulsive behavior, which can all impair learning (Boonstra et al., 2005; Gropper & Tannock, 2009).

Research has demonstrated consistently that adults with ADHD have impairments in WM abilities. Adults with ADHD perform worse compared to individuals without ADHD on tasks that require storage and manipulation of PH (Alderson, Kasper, Hudec, & Patros, 2013b; Schweitzer, Hanford, & Medoff, 2006) and VS information (Alderson, Kasper, Hudec, & Patros, 2013b). Adults with ADHD have poor performance compared to individuals without ADHD on tasks requiring inhibition of pre-potent responses (e.g. reading a word rather than identifying its color during a Stroop task) and changing response patterns in response to feedback (Boonstra et al., 2005; Nigg et al., 2005), which are common CE functions. In addition, CE functioning is significantly reduced in adults diagnosed with ADHD when a latent variable statistical approach

was used to isolate CE and subsidiary WM (e.g. VS and PH storage/rehearsal) components (Alderson, Hudec, Patros, & Kasper, 2013a).

1.4 WM and Arousal

Understanding the relationship between ADHD-related CE impairments and arousal is of particular importance, as three theoretical models of ADHD suggest that CE and arousal are linked; however, that link is not understood well. Barkley's Behavioral Inhibition model postulates behavioral inhibition is the core deficit of ADHD that influences the domains of executive functioning, including WM and self-regulation of affect, motivation, and arousal (Barkley, 1997). This model defines arousal as the central nervous system's ability to be attentive and responsive to stimuli (Barkley, 1997). The Cognitive-Energetic Model of ADHD proposed by Sergeant and colleagues (1999) suggests "state" factors such as, effort, arousal, and activation influence components of cognitive processing; whereas executive functioning, effort, and task parameters are thought to influence arousal. This model defines arousal as physiological changes time-locked to stimuli (Sergeant et al., 1999). Rapport and colleagues (2008) suggest that excessive motor behavior, an analog for arousal, is a byproduct of parametrically taxing a child's CE capacity in their WM Model. Rapport and colleagues suggest that hyperactive/impulsive behavior observed in ADHD samples might stem from increasing WM demands (Rapport et al., 2008). While these models associate arousal and cognitive performance the relationship has not been elaborated. No study to date has examined the extent to which CE functioning demands influence arousal in adults with clinically significant ADHD symptoms.

The lack of knowledge regarding the relationship between CE functioning and arousal may reflect a methodological limitation. Research was often limited to resting paradigms and simple tone discrimination tasks because of the capabilities of physiological recording

equipment. Frequently, EDLs are studied in conjunction with electroencephalograms, which demand minimal movement and, in fact, can be disrupted by simple eye blinks. Traditional EDA equipment generally inhibits freedom of movement, a characteristic feature of ADHD, which can create movement artifacts in the EDA data.

Wireless sensors may have two advantages over traditional EDL measurement methods. First, in traditional measurement methods, electrolyte paste is applied to the skin to facilitate the circuit connection between the skin and the electrodes. The paste diffuses normally into the skin and hydrates the outer layer of skin. This hydration may mimic the hydration caused by perspiration and confound EDL measurement. Second, in traditional EDL measurement, sensors are worn on the medial or distal joints of the index and middle fingers of a participant's non-dominant hand to minimize movement artifacts; however, significant reduction of artifacts is not always achievable and can reduce the amount of data available for analysis (Fowels, 2008; Poh, Swenson, & Picard, 2010). Wireless sensors are worn on the inside of the wrist permitting greater freedom of movement and reduction in artifacts. Placing wireless sensors on a participant's non-dominant hand may further minimize motion artifacts and permit participants to use their dominant hand to complete a cognitive task.

1.5 Hypotheses

The present study examined within- and between-group performance differences on tasks designed based on Baddeley's WM model (Tier I). Additionally, the study examined EDLs while (a) systematically increasing CE demands and (b) controlling for storage capacity (Tier II) in adults with and without clinically significant symptoms of ADHD. This study used unique methodology and physiologic recording equipment, which may provide additional data because of reduced motion artifacts compared to traditional physiologic recording equipment.

Tier I: CE Performance. Based on research conducted by Alderson, Kasper, Hudec, and Patros (2013) and Schweitzer, Hanford, and Medoff (2006), performance on a CE task was expected to decrease as a function of increasing CE processing demands for all participants (hypothesis Ia). In addition, adults with clinically significant ADHD symptoms were expected to demonstrate more impaired performance than adults without clinically significant ADHD symptoms (hypothesis Ib).

Tier II: EDLs. Based on research examining EDLs in ADHD samples (Satterfield & Dawson, 1971; Shibagaki, Yamanaka, & Furuya, 1993; Hermens et al., 2004; Iaboni, Douglas, & Ditto, 2006), EDLs for all participants were expected to decrease as a function of increasing CE processing demands (hypothesis IIa). In addition, EDLs for adults with clinically significant ADHD symptoms were expected to be lower than EDLs for adults without clinically significant ADHD symptoms (hypothesis IIb).

2. Methods

2.1 Measures

Demographic questionnaire. A brief questionnaire was created to obtain demographic information from the participants. The measure assessed factors such as age, ethnicity, gender, years of education, and history of ADHD diagnosis.

Adult ADHD self-report scale (ASRS, World Health Organization, 2005). The ASRS is a 6-item self-report measure designed by the World Health Organization and researchers at New York University and Harvard Medical Schools to measure attention problems in adults. The widely used measure provided a five-point Likert scale for participants to rate how often they have engaged in the described behaviors (e.g., "*How often do you have difficulty concentrating on what people say to you, even when they are speaking to you directly?*") over the past six months. This measure has a sensitivity of 68.7%, a specificity of 99.5%, and a Cohen's K of .76 in community samples and an internal consistency for self ratings of .88 (Adler et al., 2006; Kessler et al., 2005). Higher scores on this measure indicated participants had significant attention problems and/or increased hyperactive/impulsive behavior. This measure was used to screen for ADHD symptoms.

Mini international neuropsychiatric inventory (MINI; Sheehan, Harnett-Sheehan, Sheehan, and Gray, 2010). The MINI is a widely used structured clinical interview to screen for psychiatric disorders according to DSM-IV-TR criteria. The MINI has adequate reliability with the Structured Clinical Interview for the DSM-III-R with specificities above .85 and Cohen's K values ranging from .43 to .90 for all disorders assessed in community samples (Sheehan et al., 1998). This measure was used to screen participants for co-morbid disorders and the active psychosis exclusion criteria for participation in this study.

Wechsler abbreviated scales of intelligence, second edition (WASI-2, Pearson, 2011).
The WASI-2 is an abbreviated intelligence battery consisting of subtests similar to those on the
Wechsler Adult and Child Intelligence Scales. The WASI-2 can be administered in a 2- or 4-
subtest format. This study used the 2-subtest format (vocabulary and matrix reasoning), which
has an average internal consistency of .94 with established full battery intelligence assessments
like the Wechsler Adult Intelligence Scales 4th edition (McCrimmon & Smith, 2013). The
WASI-2 was used to screen potential participants for the intellectual capacity exclusion criteria
for participation in this study.

Barkley adult ADHD rating scale-IV self-report: current symptoms (BAARS-IV
Current, Barkley, 2011). The BAARS-IV Current is a 30-item self-report measure developed
by Barkley (2011), in which participants indicated how often they experience the listed
symptoms of ADHD on a 4-point Likert scale ranging from 1 "*Never or Rarely*" to 4 "*Very*
Often". The measure has four subscales measuring symptoms related to Inattention,
Hyperactivity, Impulsivity, and Sluggish Cognitive Tempo domains of ADHD. DSM-IV criteria
subscales are internally consistent (inattention: .90, hyperactivity: .78, impulsivity: .91, ADHD
total score: .91) and have adequate test-retest reliability (2-3 week interval, inattention = .66,
hyperactivity = .72, impulsivity = .76, ADHD total score = .75; Barkley, 2011). Individuals with
a total ADHD symptom count in the 93rd percentile and above are considered to have clinically
significant symptoms of ADHD (Barkley, 2011). Higher scores on this measure indicated
participants had more difficulties with inattention and increased hyperactive/impulsive behavior.
This measure was used to determine diagnostic status of participants in the study.

Barkley adult ADHD rating scale-IV self-report: childhood symptoms (BAARS-IV
Child, Barkley, 2011). The BAARS-IV Child is a 20-item self-report measure developed by

Barkley (2011), in which participants indicated how often they experienced the listed symptoms of ADHD during the period of ages 5-12 on a 4-point Likert scale ranging from 1 "*Never or Rarely*" to 4 "*Very Often*". The measure has two subscales measuring symptoms related to the Inattention and Hyperactivity/Impulsivity dimensions of ADHD. Each of the subscales is internally consistent (inattention = .94, hyperactivity/impulsivity = .91 ADHD total score = .95) and has adequate test-retest reliability (2-3 weeks interval, inattention = .73, hyperactivity/impulsivity = .82, ADHD total score = .79; Barkley 2011). Individuals with a total symptom count in the 93rd percentile and above are considered to have clinically significant symptoms of ADHD (Barkley, 2011). Higher scores on this measure indicated participants had more difficulties with inattention and increased hyperactive/impulsive behavior. This measure was used to determine diagnostic status of participants in the study.

  Beck depression inventory-2 (BDI-II, Beck, Steer and Brown, 1996). The BDI-II is a 21-item self-report measure of the severity of depression symptoms developed by Beck, Steer, and Brown (1996), which instructs participants to endorse the presence of each symptom using a 4-point Likert scale ranging from 0 (symptom was not present) to 3 (symptom was interfering with daily life). The measure has an internal consistency of .92 in outpatient samples and .93 in college student samples. The measure has a test-retest reliability of .93 for a one-week interval. Higher scores on this measure suggest participants experienced more symptoms of depression. This measure was used to assess severity of depression symptoms in study participants.

  Beck anxiety inventory (BAI; Beck, Steer, and Brown, 1997). The BAI is a 21-item self-report measure of the severity of anxiety symptoms developed by Beck and Steer (1997), which instructs participants to evaluate how bothersome each statement was to them using a 4-point Likert scale ranging from 0 "*Not at all*" to 3 "*Severely; I could barely stand it*". The

measure has an internal consistency of .92 in outpatient samples. The measure has test-retest reliability of .75 for a one-week interval. Content on this measure corresponds to DSM-IV-TR diagnosis of anxiety and significantly correlates with trait (.58) and state (.47) anxiety constructs on State-Trait Anxiety Scale (A. Osman, Kopper, Barrios, Osman, & Wade, 1997). Higher scores on this measure indicated participants endorsed more symptoms of anxiety. This measure was used to assess severity of anxiety symptoms in study participants.

2.2 Central Executive (CE) Task

Level setting (LS). The LS task was designed to assess participants' capacity to store and manipulate items in PH short-term memory (STM). This task ensured that participants were given only the number of items that they could manipulate reliably (at least 60% of the time) and not overwhelm the PH STM. Performance data from this task was used to establish the participant's STM span. A participant's STM span was set at the highest set size condition where the participant responded correctly to at least 60% of trials, which is comparable to the 50% recommended in empirical literature (Conway, Kane, & Bunting, 2005). Participants were given five trials at four set size conditions (set size 4, 5, 6, and 7) for a total of 20 trials.

General description. The CE task required participants to listen to a series of digits (1-9) and one letter presented at 1s intervals. Set sizes for the CE conditions ranged from 4 to 7 items, which was determined by the LS task described previously. Participants listened to a computerized audio presentation of stimuli recorded from AT&T Natural Voices Text to Speech software (AT&T Labs Research, Bedminster, NJ; http://www2.research.att.com/~ttsweb/tts/demo.php) with an inter-stimulus interval of 1 second. After participants listened to the numbers and letter from the computer program, they were asked

to provide a verbal response. Participants were presented with 12 trials at each set size (see Table 1. for summary of task demands).

Participants completed one LS task and the 5 CE conditions programmed in SuperLab Pro 3.0 (Cedrus Corp., San Pedro, CA), while the wireless sensor was worn. The CE task consisted of five conditions: *Forward*, *Backward*, *Low to High*, *Low to High +1*, and *Plus 1* conditions. The purpose of these tasks was to increase CE functioning demands while consistent storage demands were maintained. In the *Forward* condition, participants were instructed to repeat the digits exactly as presented (e.g. if presented 2, B, 5, 7, the participant should have responded 2, B, 5, 7). The purpose of the *Forward* condition was to assess STM storage capacity. In the *Backward* condition, participants were instructed to repeat the digits in reverse order (e.g. if presented 2, B, 5, 7, the participant should have responded 7, 5, B, 2). The purpose of the *Backward* condition was to keep STM capacity constant and increase the CE functioning demand incrementally. In the *Low to High* condition, participants were instructed to rearrange the digits in order from lowest to highest and place the letter at the end of the response (e.g. if presented 2, B, 5, 7, the participant should have responded 2, 5, 7, B). The purpose of the *Low to High* condition, and all subsequent task conditions, was to introduce additional CE functioning demands and engage WM while STM capacity was kept constant. In the *Low to High +1* condition, participants were instructed to rearrange the digits in order from lowest to highest, with the letter last, after adding one to each item (e.g. if presented 2, B, 5, 7, the participant should have responded 3, 6, 8, C). In the *Plus 1* condition, participants were instructed to repeat the stimuli in the order presented, but add 1 to each item (e.g. if presented 2, B, 5, 7, the participant should have responded 3, C, 6, 8).

Research assistants, blind to diagnostic status, coded participants' responses for the CE task conditions for accuracy. If the reliability, or agreement of both research assistants, of the coded responses was below 80%, the video recording was reviewed by the coders and re-scored individually.

2.3 Control Tasks

Paint tasks. The paint tasks required participants to sit in front of a computer screen and create a drawing using Microsoft Paint for five minutes at the beginning (*PrePaint)* and end of every experimental session (*PostPaint*). This task was designed to control for EDL fluctuations across sessions.

Plus 1 fluency task. The plus 1 fluency task required participants to listen to twelve single digit (1-9) or alphabetic letters (A-Z) via a computerized audio presentation of stimuli recorded from AT&T Natural Voices Text to Speech software (AT&T Labs Research, Bedminster, NJ; http://www2.research.att.com/~ttsweb/tts/demo.php) programmed in SuperLab Pro 4.0 (Cedrus Corp., San Pedro, CA). After each stimulus, participants were asked to verbally add one to the number or move the letter up one serial position (e.g. 2 becomes 3, and C becomes D). Participants were asked to respond as quickly as they could and then pressed the space bar to advance to the next item. This task was designed to control for individual differences in addition fluency.

2.4 Electrodermal Level (EDL) Data

EDL data was collected concurrently at 16hz for all task conditions. For the CE and Paint control conditions, EDL data was downloaded from the wireless sensors and was converted from a proprietary file type into a text file using software from the manufacturer of the wireless sensor (Affectiva, Waltham, MA). This text file was used for time coding and analysis in Microsoft

Excel. Timing data for each task was obtained in vivo, along with video recordings using Noldus The Observer XT v.11 (Noldus Information Technology, Wageningen, Netherlands), and then was exported to Microsoft Excel. EDLs for each task were calculated in order to quantify physiological arousal.

2.5 Setting

All experimental sessions were conducted according to an IRB approved protocol in a university psychology department research lab. All participants completed the experimental protocol individually. For the clinical intake during session 1, which included the MINI and the WASI-2, all participants were seated in a caster wheel task chair across a small table facing the experimenter. For all experimental tasks, participants were seated in the same caster wheel task chair approximately 2 feet in front of a computer on which the experimental tasks were programmed in SuperLab Pro 3.0 (Cedrus Corp., San Pedro, CA) and SuperLab Pro 4.0 (Cedrus Corp., San Pedro, CA).

2.6 Apparatus

Participants wore a wireless sensor (Affectiva Inc. Waltham, MA) on the wrist of their non-dominant hand during all experimental sessions. The sensor was a small wearable wireless device designed to measure electrodermal activity with standard Ag/AgCl electrodes (Wilder-Smith, 2012). The wireless sensor provided a simple way to measure EDLs and permitted free movement within the laboratory setting (Wilder-Smith, 2012). Traditionally, EDA has been measured on the medial and distal joints of the index and middle fingers of a participant's non-dominant hand (Miller & Long, 2008; Poh et al., 2010). The wireless sensors measured EDA from the ventral side of a participant's wrist. This location has a significant correlation ($r = .93$, $p < .0001$) to the traditional measurement location on the joints of a participant's index and middle

fingers (Poh et al., 2010). This sensor has been used to monitor and predict pre-seizure sympathetic nervous system activity in an ambulatory setting in conjunction with other physiological sensors (Poh et al., 2012).

2.7 Procedures

During the initial telephone contact, trained laboratory personnel screened potential participants for attention problems, via the ASRS, and medication status to determine eligibility for the study. After the initial telephone screening, eligible participants were scheduled for three, two-hour individual experimental sessions. Participants were compensated with $10 gift cards to a national retail store for each of the three sessions.

At the initial laboratory visit, participants were given the MINI to assess for potential psychopathology and the WASI-2 to estimate intellectual capacity. ADHD symptom status was determined by the administration of the BAARS-IV Current and BAARS-IV Child during the initial visit. Participants with a total symptom count in the 93rd percentile or higher on both of these measures, which indicate clinically significant symptoms, was included in the group of adults with clinically significant ADHD symptoms (henceforth referred to as the ADHD group). The order of all CE task conditions was counterbalanced across participants to control for possible order effects on task performance.

2.8 Participants

Twenty-four participants ages 18 to 50 years-old with and without a previous diagnosis of ADHD and/or suspected attention problems were recruited or referred to the Behavior and Learning Lab through the research lab's website and community/campus resources for the present study participated in this study (see Table 2.). The systematic recruitment plan approved by the IRB included the following: (1) approved advertisements posted on general bulletin

boards at the University of Tennessee; (2) a brief description posted on the Behavior and Learning Lab's website; (3) a brief description of the study and an approved advertisement posted on the University of Tennessee Psychology Department's research participation system website; (4) approved advertisements made available to individuals who attended ADHD educational seminars conducted by the Behavior and Learning Lab; and (5) approved advertisements posted on community bulletin boards with prior approval from appropriate departments and/or administrators.

Individuals with gross neurological, sensory, serious motor impairment; history of seizure disorder, active psychosis, or an intellectual capacity of less than 80 were excluded from participation due to the task demands of the study. Individuals were excluded if they were prescribed/using psychotropic medication or using other medication that might affect EDL measurement (e.g. benzodiazepines, beta-blockers, antipsychotic and stimulant medications). Participants prescribed stimulant medication for ADHD were required to abstain from taking their stimulant medication 24 hours prior to experimental sessions. In addition, participants were asked to abstain from consumption of caffeine and alcohol for at least 2 hours prior to and during study visits because of their actions as a central nervous system stimulant and depressant respectively. Participants' disclosure of using these substances 2 hours or less prior to participation in the study were to be noted in a log prior to participation, but no participants endorsed using these substances prior to or during the experimental sessions.

Participants were grouped by diagnostic status according to their scores on the BAARS-IV Current and Childhood symptom reports. The ADHD group consisted of those individuals whose total symptom count on both the BAARS-IV Current and BAARS-IV Childhood symptom inventories were in the 93rd percentile or above indicating the presence of clinically

significant ADHD symptoms. The Control group consisted of those participants that had a negative screen on the ASRS and total symptom count scores below the 93rd percentile on both the BAARS-IV Current and BAARS-IV Childhood symptom inventories. Participants included 13 individuals in the Control group (6 female; 7 male) and 11 individuals in the ADHD group (4 female; 7 male). Two-tailed t-tests were conducted to assess for any significant differences in age, years of education, and WASI-2 composite scores between the diagnostic groups in order to control for possible influences on CE task performance.

There were no significant differences in sex ratios in the control group ($\chi^2(1) = 0.08$, $p = .782$), ADHD group ($\chi^2(1) = 0.82$, $p =. 366$), and total sample ($\chi^2(1) = 0.67$, $p = .414$). Two-tailed t-tests indicated the groups were comparable on age ($t(22) = 0.89$, $p = .381$), years of education ($t(22) = 1.50$, p = .149), and WASI-2 scores ($t(22) = 0.14$, $p = .888$; (see Table 3.). As expected, the groups were significantly different on the ASRS phone screen ($t(22) = -2.81$, $p =.010$), BAARS-IV total current ($t(22) = -3.49$, $p =.002$) and total childhood ($t(22) = -6.74$, $p <.001$) symptom counts of ADHD. Individuals in the ADHD group reported an average of 10 current and an average of 13 childhood symptoms of ADHD. In contrast, individuals in the control group reported an average of 5 current and an average of 3 childhood symptoms of ADHD. The groups were comparable on measures of depression (BDI ($t(22) = -1.46$, $p =. 159$) and anxiety (BAI ($t(22) = -0.92$, $p = .370$) severity. See Table 4. for MINI results by diagnostic group.

3. Results

3.1 Power Analyses

A priori power analyses for each hypothesis were conducted to determine sample size. The articles cited below provide only the ANOVA *F* statistics, as such a conversion to Cohen's *d* was necessary as outlined by methodological literature (Rosnow & Rosenthal, 1996; Thalheimer & Cook, 2002).

Tier I: CE Task Performance.

An effect size (*ES*) for differences in CE task performance in individuals with and without clinically significant ADHD symptoms was used to determine sample size to detect differences in CE performance. An ES of $d = .603$ ($\eta^2 = .090$)[1] for differences in CE task performance in adults with and without clinically significant ADHD found in an empirical study was used (Alderson, Hudec, Patros, & Kasper, 2013a).

A power analysis using G*Power 3.1 for Macintosh (Faul, Erdfelder, Lang, & Buchner, 2007) suggested that for an *ES* for CE tasks of $\eta^2 = .09$, $\alpha = 0.05$, power $(1-\beta) = 0.80$, 2 groups and 5 tasks a total of 14 subjects was estimated to be needed for a repeated measures ANOVA to detect differences in task performance.

Tier II: Electrodermal Levels.

An *ES* for a resting paradigm was used to determine the necessary sample size to detect differences in EDLs in adults with and without clinically significant ADHD symptoms. An *ES* of

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[1] This conversion was made on recommendations outlined in methodological literature (Rosnow & Rosenthal, 1996; Thalheimer & Cook, 2002)

$d = .470$ ($\eta^2 = .051$)[2] for differences in EDLs in adults with and without ADHD found in an

empirical study was used (Hermens et al., 2004).

A power analysis using G*Power 3.1 for Macintosh (Faul et al., 2007) suggested that for

an *ES* for PH WM tasks of $\eta^2 = .051$, $\alpha = 0.05$, power $(1-\beta) = 0.80$, 2 groups and 7 tasks a total of

20 subjects was estimated to be needed for a repeated measures ANOVA to detect differences in

EDLs.

3.2 Tier I: CE Task Performance

All variables were screened for inaccurate data entry, missing data, and outliers prior to

data analysis. The data was examined for outliers through boxplots generated in SPSS 22 (IBM

Corporation, 2013). These plots identified outliers as values more than 1.5 times greater than the

interquartile ranges of the variables based on Tukey's hinges (Tukey, 1977). No outliers were

identified through this process. However, one control participant had missing data on the CE

Forward condition. This participant was removed from the ANOVA evaluating CE Performance

and a total of 23 participants (12 Control; 11 ADHD) were included in the ANOVA (see Table

5.).

To examine performance associated with CE functioning while (a) systematically

increasing CE demands and (b) controlling for storage capacity in adults with and without

clinically significant symptoms of ADHD a 2 (Control, ADHD) x 5 (*Forward*, *Backward*, *Low

to High*, *Low to High +1*, *Plus One*) repeated-measures ANOVA was conducted. The ANOVA

had a between-subjects factor of diagnostic group and within-subjects factors of the 5 CE tasks.

Bonferroni corrections were used to control for multiple comparisons.

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[2] This conversion was made on recommendations outlined in methodological literature (Rosnow
& Rosenthal, 1996; Thalheimer & Cook, 2002)

Hypothesis Ia. The assumption of sphericity was violated, $X^2(9) = 22.71$, $p = .007$. Therefore, the degrees of freedom were adjusted with the Greenhouse-Geisser correction ($\varepsilon = .71$). The group x condition interaction effect was not significant, $F(2.82, 59.19) = 0.31$, $p = .806$, $\eta^2 = .015$, which suggested that CE performance does not change as a function of task conditions within levels of diagnostic group. However, there was a significant main effect of task performance, $F(2.82, 59.19) = 5.32$, $p = .003$, $\eta^2 = .202$. There was a significant linear trend in the data (see Figure 2.), $F(1, 21) = 17.87$, $p < .001$, $\eta^2 = .460$, which suggested all participants performed significantly better on the *Forward* condition relative to both the *Plus One* condition ($p < .001$) and the *Low to High Plus One* ($p = .003$) condition.

Hypothesis Ib. There was no main effect of diagnostic group on CE performance, $F(1, 21) = 0.00$, $p = .996$). This suggested that adults with clinically significant ADHD symptoms do not demonstrate significantly impaired CE functioning compared to adults without clinically significant ADHD symptoms.

3.3 Tier II: EDLs

All variables were screened for inaccurate data entry, missing data, and outliers prior to data analysis. The data was examined for outliers through boxplots generated in SPSS 22 (IBM Corporation, 2013). These plots identified outliers as values more than 1.5 times greater than the interquartile ranges of the variables based on Tukey's hinges (Tukey, 1977). Four participants (3 Control and 1 ADHD) with a total of 9 outliers were identified. Outliers were corrected via a mean substitution procedure as outlined in Tabachnick and Fidell (2007) where the group mean for each EDL task was substituted for the outlier variable. Four (3 Control, 1 ADHD) participants had missing data and were removed from the ANOVA. A total of 20 (10 Control; 10 ADHD) participants were included in the ANOVA (see Table 6.).

To examine electrodermal levels while (a) systematically increasing CE functioning demands and (b) controlling for storage capacity in adults with and without clinically significant symptoms of ADHD a 2 (Control, ADHD) x 7 (*PrePaint, Forward, Backward, Low to High, Low to High +1, Plus One, PostPaint*) repeated-measures ANOVA was conducted for average EDLs during the computerized tasks. The ANOVA had a between-subjects factor of diagnostic group and within-subjects factors of the 5 CE tasks and 2 Paint tasks. Bonferroni corrections were used to control for multiple comparisons.

Hypothesis IIa. The assumption of sphericity was violated ($X^2(20) = 47.25$, $p = .001$) therefore, the degrees of freedom were adjusted with the Greenhouse-Geisser correction ($\varepsilon = .53$). There was no main effect of Task Condition across diagnostic groups, $F(3.19, 57.42) = 2.26$, $p = .088$, on EDLs. There was a significant quadratic trend in the data (see Figure 3.), ($F(1,18) = 6.40$, $p = .021$, $\eta^2 = .262$, which suggested that EDLs may change in response to task condition difficulty. There was a significant interaction of EDL x Group interaction, $F(3.19, 57.42) = 3.74$, $p = .014$, $\eta^2 = .172$, on EDLs. This finding suggested that EDLs are affected differently by task condition for the ADHD and Control groups. Because of the significant interaction of Task Condition x Diagnostic Group, post-hoc analyses were conducted for simple effect of diagnostic group. Because homogeneity of variance could not be assumed as the data violated the assumption of sphericity, as noted above, diagnostic groups were analyzed using separate error terms. For the ADHD group, the assumption of sphericity was violated ($X^2(20) = 53.86$, $p < .001$), therefore, the degrees of freedom were adjusted with the Greenhouse-Geisser correction ($\varepsilon = .45$) and there was no significant effect of task, $F(2.72, 24.49) = 1.52$, p = .237. As such, for individuals with clinically significant symptoms of ADHD, EDLs are unaffected by task condition difficulty. However, for the Control group, the assumption of sphericity was

violated ($X^2(20) = 41.38$, $p = .006$), therefore, the degrees of freedom were adjusted with the Greenhouse-Geisser correction ($\varepsilon = .47$) and there was a significant effect of task, $F(2.82, 25.41) = 3.63$, p $= .028$, $\eta^2 = .288$. Therefore, for individuals without clinically significant ADHD symptoms, EDLs are influenced by task condition difficulty, specifically in response to WM tasks.

Hypothesis IIb. There was no main effect of diagnostic group on EDLs ($F(1,18) = 0.04$, $p = .854$), which suggested that adults with clinically significant ADHD symptoms do not differ in EDLs related to task conditions compared to adults without clinically significant ADHD symptoms.

3.4 Tier III: Plus 1 Fluency

A two-tailed *t*-test was conducted to assess for any significant differences in addition fluency between groups. Differences in simple addition fluency may have influenced CE performance results if the two groups differed on addition fluency performance. No difference in addition fluency was found between groups (see Table 7.), $t(21) = -1.66$, p $= .113$, and, therefore, the data was not analyzed further.

4. Discussion

This study examined performance associated with CE functioning (Tier I) and EDLs (Tier II) while (a) systematically increasing CE demands and (b) controlling for storage capacity in adults with and without clinically significant symptoms of ADHD. This study used tasks designed based on Baddely's WM model with unique methodology and physiologic recording equipment. This was the first study to directly measure performance and EDLs during a series of CE task conditions in adults with and without clinically significant symptoms of ADHD, as previous studies have either examined EDLs in adults with and without ADHD using resting paradigms (Hermens et al., 2004) or used a latent variable statistical approach to estimate CE functioning (Alderson, Hudec, Patros, & Kasper, 2013a).

The results of Tier I, a significant effect of task condition, but no effect of diagnostic group on CE performance, supported the hypothesis that for all participants, performance decreases as a function of increasing CE processing demands (IIa). The analysis suggested CE performance decreases when engaging WM rather than only STM. Participants, both with and without clinically significant symptoms of ADHD, performed better on task conditions requiring use of only STM (*Forward*) rather than WM (*Plus One* and *Low to High Plus One*). This finding suggested that CE performance decreases for all participants as a function of task difficulty and increasing CE processing demands. This was consistent with studies finding that STM and WM are cognitively separate components (Baddeley, 2012; Engle, 2002). The present study did not document between-group performance differences (Ib). The analysis suggested that adults with clinically significant ADHD symptoms do not demonstrate significantly impaired CE performance compared to adults without clinically significant ADHD symptoms overall.

In this analysis, an effect size of $\eta^2=.202$ was found for differences in CE performance by task condition. A recent latent variable analysis suggests that overall CE performance has an effect size of $\eta^2=.090$[3] (Alderson, Hudec, Patros, & Kasper, 2013a). This discrepancy in effect size may be based on several factors. First, this study directly measured the CE rather than utilizing a statistical approach to measurement. Second, the current study examined differences between groups based on symptoms of ADHD rather than a confirmed diagnosis. Finally, the current study utilized CE tasks based on both STM and WM rather than using only WM tasks. Future studies could examine if CE performance varies depending on the type of cognitive tasks, either WM alone or WM and STM, utilized.

The results of Tier II, a significant interaction between EDLs and diagnosis, partially supported the hypothesis that as CE functioning demands increase average EDLs will decrease for all participants (IIa). The analysis for hypothesis IIa suggested that as CE performance demands increase, EDLs will decrease only for adults without clinically significant ADHD symptoms and there was no influence of CE performance demands on EDLs for adults with clinically significant ADHD symptoms. However, the present study did not document that EDLs for adults with clinically significant ADHD symptoms was lower than EDLs for adults without clinically significant ADHD (IIb). The analysis suggested that adults with clinically significant ADHD symptoms do not demonstrate significantly decreased patterns of EDLs compared to adults without clinically significant ADHD symptoms. This finding was inconsistent with Hermens and colleagues (2004) where adults with ADHD demonstrated lower EDLs during a resting paradigm. This discrepancy suggests that cognitive processing demands may exert a

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[3] This effect size was originally reported in a different form and subsequently converted to current form based on recommendations from literature (Rosnow & Rosenthal, 1996; Thalheimer & Cook, 2002).

mediating or moderating effect on EDL in adults with ADHD and future studies could examine this potential relationship.

As noted in Table 4., participants in this study had several comorbid psychological disorders and some participants had multiple comorbid disorders. The most common comorbidities that could influence CE performance and EDLs were major depressive episodes (current and past) and anxiety disorders. However, there were no differences in results of the analyses when symptoms of depression or anxiety were included as covariates in the analyses.[4]

The primary limitation to the generalizability of the current study was the unique sample characteristics. Two primary characteristics of our sample differ from more traditional ADHD samples. First, the sample for the current study had a roughly equal gender distribution, which was uncommon, as research has demonstrated a 3:1 ratio of males to females being diagnosed with ADHD (Barkley, 1997). This difference in gender ratios is particularly salient as all of the models cited in this study (Barkley, 1997; Rapport et al., 2008; Sergeant et al., 1999) and Alderson's (2013b) meta-analysis of WM in adults with ADHD were constructed or done only with male subjects. Second, the convenience sample used in this study may restrict the generalizability of results, as the sample had an above average WASI-2 (ADHD: $\bar{X}$ = 111.55, SD = 17.69; Control $\bar{X}$ = 112.38, SD =10.83) and more than 12 years of education for both groups. As such, participants may have been better able to allocate cognitive resources as Engle (2002) suggests a link between IQ and performance on WM tasks. This level of education for the ADHD group was unusual as research suggests adults with ADHD and clinically significant

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[4] Tier Ia: $F(2.79, 53.02) = 3.63$, $p =.021$, Tier Ib: $F(1,19) = 0.00$, $p = .992$; Tier IIa overall: $F(3.02, 48.34) = 0.83$, $p = .483$, Tier IIa Diagnosis x EDA interaction $F(3.02, 48.34) = 3.05$, $p = .037$, Tier IIb: $F(1,16) = 1.08$, $p = .314$

ADHD symptoms typically have less education, are less likely to graduate from high school, and are less likely to attend college (Barkley, 2006a).

Recent analyses of CE functioning in college students with and without ADHD, similar to the current study, have demonstrated mixed results. One study noted that WM was impaired in college students with ADHD compared to college students without ADHD, but GPAs for each of the groups was comparable noting that the deficits in functioning between groups was quite subtle (Gropper & Tannock, 2009). In addition, a recent study has found differences in executive functioning between college students with and without an ADHD diagnosis. This study acknowledged that differences were found using self-report measures, but found minimal discrepancies using objective laboratory based measures of executive functioning, specifically sustained attention, inhibition, and verbal abilities (Weyant et al., 2013).

Because three contemporary theoretical models of ADHD link CE functioning and arousal, future studies must target specific CE processes (e.g. focusing attention on a task, dividing attention between two or more tasks, switching attention between tasks, and interacting with long-term memory stores as needed to complete task) using both objective and self-report measures to understand ADHD-related CE deficits. In addition to understanding deficits in arousal must be further investigated using any means available, particularly during cognitive tasks. In order to improve current models of ADHD, the link between arousal and the CE is crucial to investigate to understand more fully ADHD symptoms and etiology.

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Appendices

Appendix 1. Tables

Table 1.
Examples of Task Stimuli and Responses for CE Level 4

Task Condition	Stimuli	Response 1	Response 2
Forward	2, B, 5, 7	2, B, 5, 7	–
Backward	2, B, 5, 7	2, B, 5, 7	7, 5, B, 2
Low to High	2, B, 5, 7	2, B, 5, 7	2, 5, 7, B
Low to High +1	2, B, 5, 7	2, B, 5, 7	3, 6. 8, C
Plus One	2, B, 5, 7	2, B, 5, 7	3, C, 6, 8

Note: Stimuli are presented via a computer recording and the
participants provide verbal responses with stimuli in particular
sequences based on the task condition.

Table 2.
Sex Ratios of Control and ADHD Groups

	Sex		χ^2
	Male	Female	
	n (Residual)	*n* (Residual)	
Control	7 (1.5)	6 (-1.5)	.077
ADHD	7 (.5)	4 (-.5)	.818
Total	14 (2)	10 (-2)	.667

Note: ADHD = attention-deficit/hyperactivity disorder; * *p* <
.05; ** *p* ≤ .01; *** *p* ≤ .001

Table 3.

Sample and Demographic Variables

Variable	Control		ADHD		
	$\overline{X}$	SD	$\overline{X}$	SD	*t*(22)
Age	29.46	11.77	25.64	8.61	0.89
Years of Education	16.08	1.71	14.91	2.12	1.50
WASI-2	112.38	10.83	111.55	17.69	0.14
ASRS Screener	3.54	1.56	5.09	1.04	-2.81*
BAARS-IV Adult Symptoms	5.00	4.69	10.91	3.33	-3.49*
BAARS-IV Child Symptoms	3.46	4.39	13.46	2.39	-6.74*
BDI-II	9.46	9.21	16.46	14.12	-1.46
BAI	8.77	10.39	12.18	7.28	-0.92

Note: ADHD = attention-deficit/hyperactivity disorder, *WASI*-2 Full scale IQ estimate 2 subtest version, *ASRS Screener* adult ADHD self-report scale, *BAARS-IV Current* Barkley adult ADHD Rating Scales-IV Current symptoms**,** *BAARS-IV Child* Barkley Adult ADHD Rating Scales –IV Childhood symptoms, *BDI-II* Beck Depression Inventory Second Edition, *BAI* Beck Anxiety Inventory; * *p* < .05; ** *p* ≤ .01; *** *p* ≤ .001

Table 4.
Comorbid Disorders as Assessed by MINI by Diagnostic Group

	Control		ADHD	
	n	*%*	*n*	*%*
Major Depressive Episode	4	14.30	5	17.20
Past Major Depressive Episode	6	21.40	6	20.70
Lifetime Mood Disorder with Psychotic Features	0	0.00	1	3.45
Bipolar I with Psychotic Features	0	0.00	1	3.45
Bipolar II Disorder	0	0.00	1	3.45
Manic Episode	0	0.00	1	3.45
Past Manic Episode	1	3.57	0	0.00
Hypomanic Episode	1	3.57	0	0.00
Past Hypomanic Symptoms	0	0.00	1	3.45
Generalized Anxiety Disorder	2	7.14	1	3.45
Panic Disorder, Lifetime	1	3.57	0	0.00
Panic Disorder Limited Symptom Attacks, Lifetime	0	0.00	1	3.45
Generalized Social Phobia	0	0.00	1	3.45
Obsessive-Compulsive Disorder	1	3.57	1	3.45
Post-Traumatic Stress Disorder	0	0.00	1	3.45
Alcohol Dependence	4	14.30	3	10.30
Alcohol Abuse	2	7.14	1	3.45
Non-Alcohol Substance Dependence	1	3.57	0	0.00
Non-Alcohol Substance Abuse	3	10.70	1	3.45
Poly-Substance Dependence	2	7.14	1	3.45
Anorexia Nervosa	0	0.00	1	3.45
Lifetime Antisocial Personality Disorder	0	0.00	1	3.45

Note: Percentages calculated for diagnostic groups. Some participants had multiple co-morbid disorders.

Table 5.
CE Performance Data by Diagnostic Group

	Task Performance (% Correct)						F	Task Performance Contrasts
	Forward	Backward	Low to High	Plus One	Low to High +1	Group Composite		
	$\overline{X}$ (SD)	$\overline{X}$ (SD)	$\overline{X}$ (SD)	$\overline{X}$ (SD)	$\overline{X}$ (SD)	$\overline{X}$ (SE)		
Control	86.69 (10.60)	74.81 (22.39)	73.52 (21.12)	72.05 (18.73)	62.75 (34.77)	74.00 (4.28)	2.38	F = B = LtoH = +1 > LtoH+1
ADHD	86.03 (13.00)	73.17 (26.55)	79.40 (18.81)	66.92 (22.95)	64.48 (13.31)	74.00 (4.47)	3.54[#]	F = B = LtoH = +1 > LtoH+1
Task Performance Composite	86.37 (11.54)	74.02 (23.92)	76.33 (19.82)	69.60 (20.54)	63.58 (27.03)	--		
Group F	0.91	1.78	0.05	0.84	10.54**	--		
Group Contrasts	Control = ADHD	Control = ADHD	Control = ADHD	Control = ADHD	Control < ADHD	Control = ADHD		

Note: ADHD = attention-deficit/hyperactivity disorder; F=Forward, B=Backward, LtoH=Low to High, +1= Plus One; LtoH+1= Low to High +1; * $p < .05$; ** $p \le .01$; *** $p \le .001$: [#]p is trending toward significance at .05 level

Table 6.
EDL During Tasks by Diagnostic Group

	EDL (µSiemens)								F	EDL Contrasts
	Pre-Paint	Forward	Backward	Low to High	Plus One	Low to High +1	Post-Paint	Group Composite		
	$\overline{X}$ (SD)	$\overline{X}$ (SD)	$\overline{X}$ (SD)	$\overline{X}$ (SD)	$\overline{X}$ (SD)	$\overline{X}$ (SD)	$\overline{X}$ (SD)	$\overline{X}$ (SE)		
Control	1.43 (0.93)	1.62 (1.74)	1.62 (1.52)	3.30 (2.26)	1.37 (1.33)	1.33 (1.03)	1.19 (1.11)	1.70 (0.31)	30.11*	BP =F = B = +1= LtoH+1= EP < LtoH
ADHD	1.30 (1.32)	1.12 (1.61)	1.70 (2.43)	1.40 (1.80)	1.86 (2.16)	1.95 (2.37)	1.68 (1.87)	1.572 (0.58)	1.516	BP =F = B = LtoH = +1= LtoH+1= EP
EDL Composite	1.36 (1.11)	1.37 (1.65)	1.66 (1.97)	2.35 (2.21)	1.61 (1.76)	1.64 (1.81)	1.43 (1.52)	--		
Group F	1.95	0.44	0.70	0.97[#]	2.32	5.62*	2.39	--		
Group Contrasts	Control = ADHD	Control = ADHD	Control = ADHD	Control = ADHD	Control = ADHD	Control < ADHD	Control = ADHD	Control = ADHD		

Note: ADHD = attention-deficit/hyperactivity disorder; BP= Pre-Paint, F=Forward, B=Backward, LtoH=Low to High, +1= Plus One; LtoH+1= Low to High +1; EP= Post-Paint; * $p < .05$; ** $p \leq .01$; *** $p \leq .001$; [#] p is trending toward significance at .05 level

Table 7.
Two-tailed t-test for Plus One Fluency

	Control		ADHD		
	$\overline{X}$ (%)	SD	$\overline{X}$ (%)	SD	$t(21)$
Plus One Fluency	98.08	3.65	100	0.0	-1.66

Note: ADHD = attention-deficit/hyperactivity disorder; * $p < .05$; ** $p \leq .01$; *** $p \leq .001$
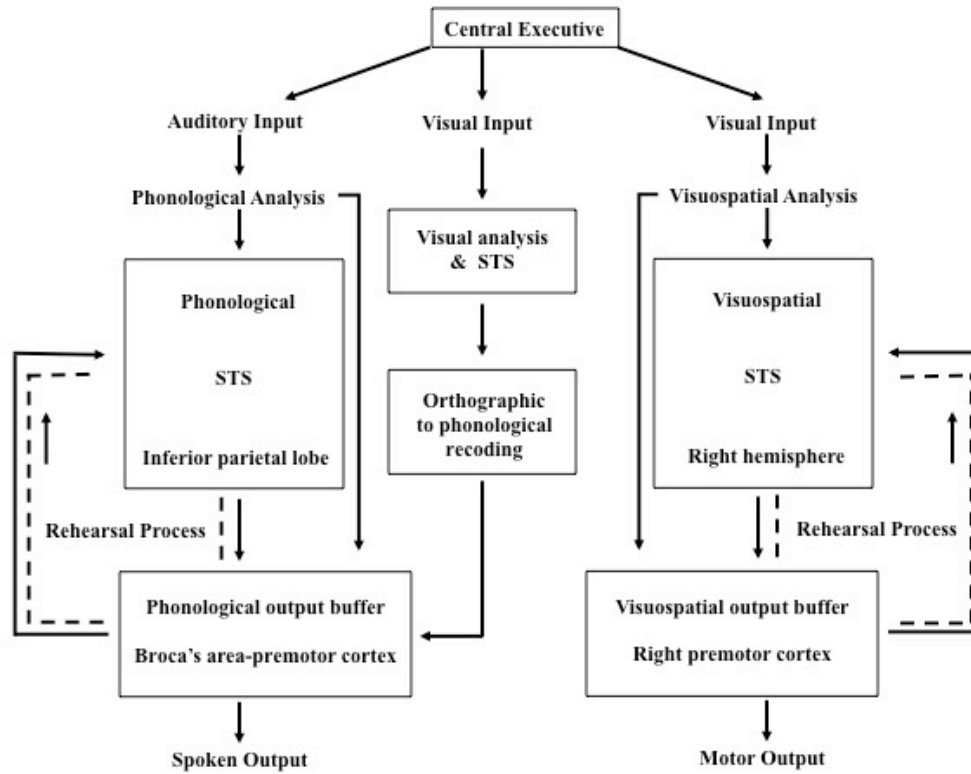
Appendix 2. Figures
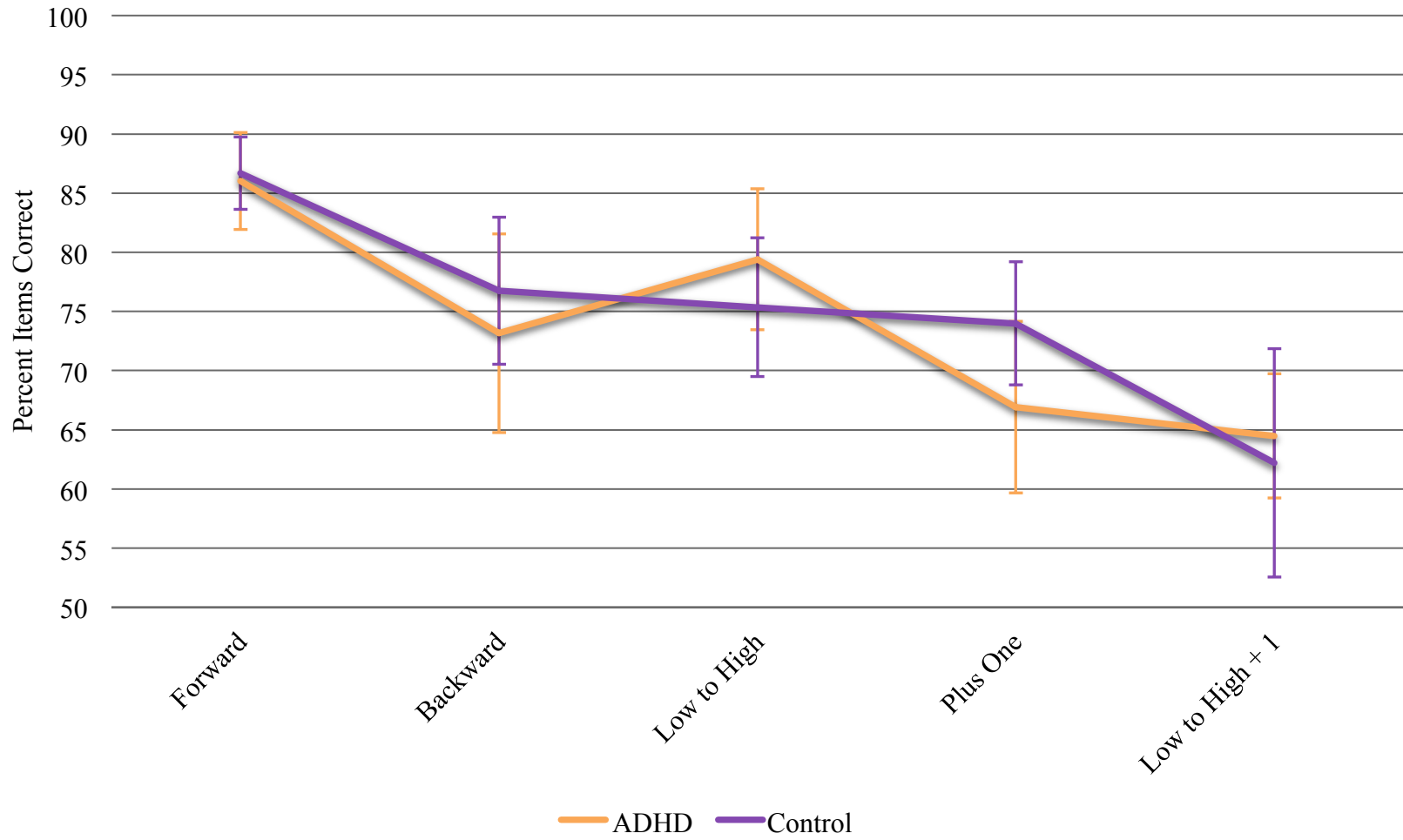
Figure 1. Baddeley's Multi-Component WM Model.

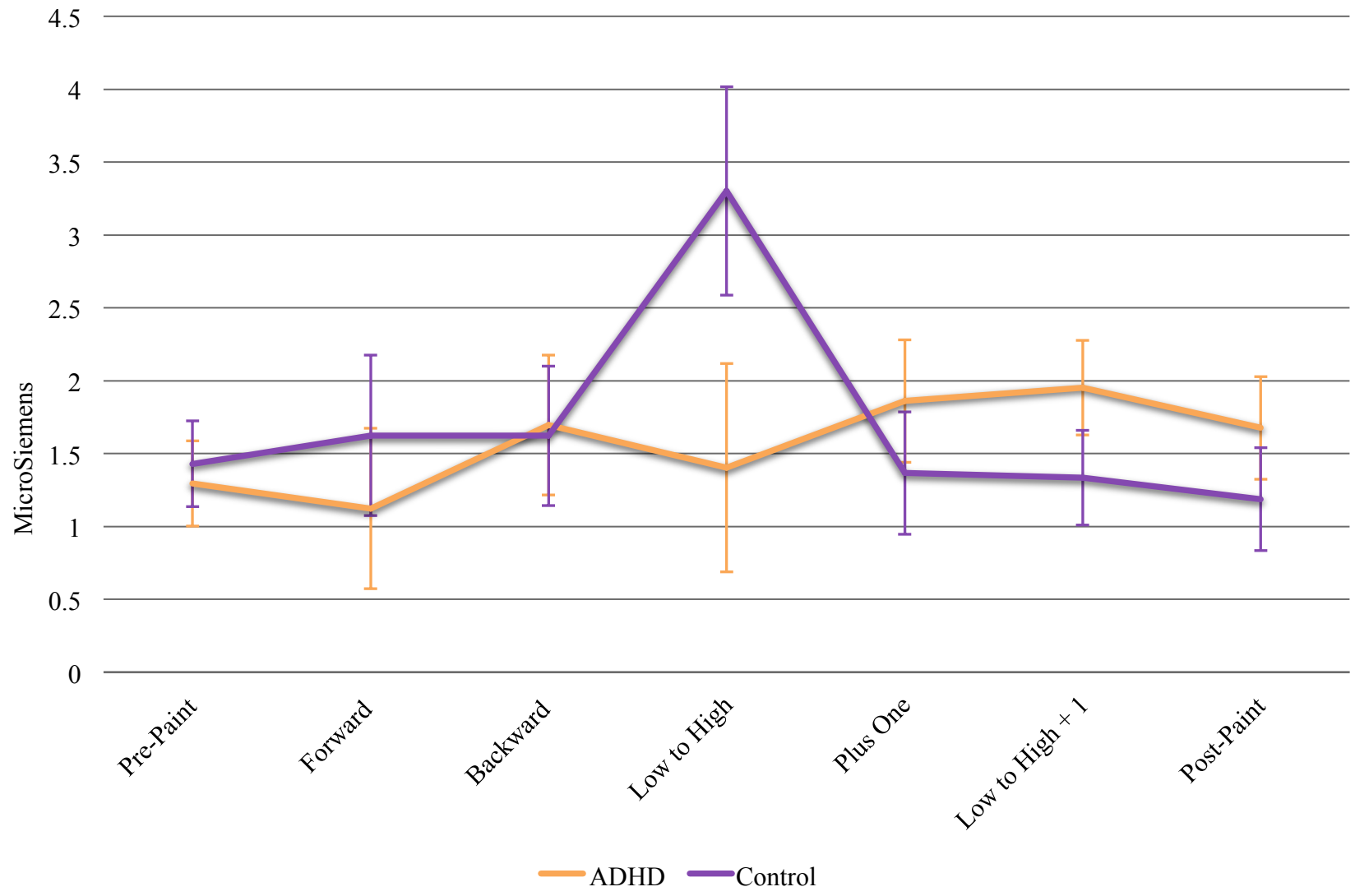Figure 2. CE Performance by Diagnostic Group.

Figure 3. EDLs by Diagnostic Group.

Vita

Megan Carl grew up in Northeast Ohio where she frequently spent time with her best friend and non-biological sister Rita Snyder-Furr (who has been a constant support to keep writing every time Megan wanted to set her manuscripts on fire). Megan graduated Magna Cum Laude from Case Western Reserve University in Cleveland, OH in 2010 with a Bachelor of Arts in Psychology (Cleve-land ROCKS! Cleve-land ROCKS!). After receiving her B.A., she became a research assistant at the Clinical Cognitive Neuroscience Laboratory at the Western Psychiatric Institute and Clinic of the University of Pittsburgh Medical Center. In August 2012, Megan began her graduate studies in Clinical Psychology at the University of Tennessee-Knoxville and became a member of the Behavior and Learning Lab at the University of Tennessee under the mentorship of Dr. Jennifer Bolden, Ph.D. (without whom this thesis would have languished as incoherent scribbles in a notebook). Megan earned her Master of Arts in Psychology in May 2015. She continues to work toward her Ph.D. in Clinical Psychology at the University of Tennessee-Knoxville and collaborate with fellow graduate students and the research assistants in the Behavior and Learning Lab. After completing her Ph.D., she hopes to return to Northeast Ohio and engage in clinical practice.