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Attention, Hyperactivity, and Cognitive Performance in Adults with Attention-Deficit/Hyperactivity Disorder (ADHD)

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I am submitting herewith a thesis written by Brianna Elizabeth Pollock entitled "Attention, Hyperactivity, and Cognitive Performance in Adults with Attention-Deficit/Hyperactivity Disorder (ADHD)." 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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Attention, Hyperactivity, and Cognitive Performance in Adults with Attention-Deficit/Hyperactivity Disorder (ADHD)

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Dedication

To my siblings, who were the first to make me curious about intellect, emotion, and human behavior, in the best possible way.

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Abstract

The extent to which Attention-Deficit/Hyperactivity Disorder (ADHD) symptoms (i.e., inattention, hyperactivity/impulsivity) are associated with ADHD-related cognitive impairments has yet to be understood. This study sought to examine between-group differences in activity level, performance on a sustained attention task and objectively measured attention, while controlling for anxiety and depression severity in a sample of adults with and without ADHD (N = 26). High precision actigraphs and behavioral codes of visual attention to task were used to examine the extent to which activity level and visual attention to task are related to performance on a sustained attention task (i.e., Continuous Performance Test, CPT). The study also sought to examine the extent to which visual attention to task mediates the relationship between activity level and errors on the CPT. The ADHD sample exhibited higher activity level rates during the CPT, while the comparison group exhibited higher activity level rates during non-cognitive control conditions (i.e., Microsoft Paint; $p < .05$). Differences in activity level between the groups did not vary as a function of anxiety or depression severity. No between-group differences were found in visual attention to task or CPT performance. Meditational analyses were not conducted due to a lack of variation in visual attention to task between the groups. Future directions for research and clinical implications are discussed.

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Chapter 1

Introduction

Attention–deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder characterized by excessive inattention and/or hyperactivity/impulsivity levels. While ADHD symptoms emerge during childhood (American Psychiatric Association, 2013), research documents the continued manifestation of ADHD symptoms into adulthood for over half of children diagnosed with ADHD (Barkley, 2006; Spencer, Biederman, & Mick, 2007). Further, increased hyperactivity/impulsivity rates are noted for adults diagnosed with ADHD during childhood who no longer meet diagnostic criteria for ADHD (i.e., ADHD in full remission; Halperin, Trampush, Miller, Marks, & Newcorn, 2008).

Understanding the continued manifestation of ADHD symptoms is of particular importance, as ADHD symptoms are related to impairments in academic, occupational, and social domains (Barkley, 2006; Rapport, Kofler, Alderson, & Raiker, 2008). Hyperactivity/impulsivity is associated with increase rates of automobile accidents, higher rates of license suspensions, as well as risky sexual behavior (Barkley, 2006). In a 14-year prospective follow-up study of young adults diagnosed with ADHD, hyperactive young adults (mean age 20-21 years) were involved in more antisocial activities (e.g., theft, felony arrests, assaults with a weapon, illegal drug possession) relative to a community comparison group (Barkley, Fischer, Smallish, & Fletcher, 2004). Even after controlling for comorbid disorders (e.g., anxiety and depression), negative life events and negative outcomes for adults who continue to meet criteria for the disorder (e.g., financial trouble, divorce or separation, and termination of employment) are associated with the severity of ADHD symptoms, particularly hyperactive/impulsive symptoms (Garcia et al., 2012).

Studies that examine inattention, as defined by omission errors (e.g., failure to identify the target) on a Continuous Performance Test, a measure of sustained attention, continue to find increase rates of omission errors by adults with ADHD (Avisar & Shaley, 2011; Jones, Craver, Lemley, & Barrett, 2008; Lis et al., 2010). A study examining attention in adults with ADHD using visual target cancellation tasks (i.e., a test of visual spatial functioning and attention) found that adults with ADHD made almost twice as many omission errors compared to a comparison group (Jones, Craver-Lemley, & Barrett, 2008).

Marked cognitive deficits are often associated with adult ADHD. Two meta-analytic reviews document deficits in overall intellectual ability (Bridgett & Walker, 2006; Frazier, Demaree, & Youngstrom, 2004) and studies document impairment in higher-order cognitive domains such as verbal fluency (Boonstra, Oosterlaan, Sergeant, & Buitelaar, 2005), inhibitory motor control (Hervey, Epstein, & Curry, 2004; Lijffijt, Kenemans, Verbaten, & van Engeland, 2005) and both spatial working memory and planning (McLean et al., 2004). Cognitive impairments are often linked to inattention symptoms; inattention symptoms are strongly linked to academic impairments (e.g., math, writing, and reading problems; Garner, O'Connor, Narad, Tamm, & Simon, 2013; Willcutt, Pennington, Olson, & DeFries, 2007), and increased reaction time variability (Kuntsi, Pinto, Price, van der Meere, & Frazier, 2014).

Chapter 2

Theoretical Background

Association between ADHD Symptoms and Cognitive Processes

The impairments associated with inattention symptoms are well documented; however, the extent to which hyperactive/impulsive symptoms are associated with cognitive impairments remains unknown (Barkley, 2006). To date, only two studies have examined the relationship between objectively measured activity level and cognitive impairment in adults diagnosed with ADHD. Lis and colleagues (2010) examined the relationship between objectively measured activity level and performance on a test of visual-spatial working memory and attention. Specifically, activity level was measured using an infrared camera that recorded movements from a reflective headband worn on the participant's forehead (Lis et al., 2010). Between-group differences were noted for omission errors, a presumed measure of inattention, rather than commission errors, a presumed measure of hyperactivity/impulsivity. Further, increased activity level rates were related to cognitive performance deficits for only the ADHD group. No relationship was found between activity level rates and task performance for the comparison group. Although the study documents the relationship between objectively measured activity level and both omission and commission errors, the findings may underestimate the relationship between activity level and task performance, as the inclusion of hand and feet movement, (e.g., fidgeting) may better clarify the extent to which activity level (and not head movements) is associated with performance on a visual-spatial working memory task.

Another study that utilized objectively measured activity level in adults with ADHD was conducted by Teicher and colleagues (2012). Participants completed a sustained attention task while infrared motion analysis cameras were used to track head and shin movements. Adults with ADHD exhibited higher head/shin movement rates and a much greater range of movement compared to controls (Teichler et al., 2012). Teichler and colleagues (2012) also found that a calculated measure of attention to task and response latency distinguished participants with ADHD from controls. On a measure of sustained attention, adults with ADHD made more commission errors relative to controls. Unlike the results obtained by Lis and colleagues (2010), no significant between-group differences were observed for omission errors. Although Teicher and colleagues (2012) utilized an objective measure of activity level, the inattention measure (i.e., attention to task variable) was based on performance rather than behavioral codes (i.e., visual attention to task). Thus, this measure of inattention may not capture important behavioral components of attention, as commission/omission errors may not *always* be analogous to visual attention to task. For example, a participant may be attentive to the task (e.g., head oriented to the computer screen) and still commit an omission/commission error. Studies examining the participant's behavior during these sustained attention tasks, independent of task performance, are needed to understand the relationship between behaviors displayed during the task and cognitive impairments.

The inconsistent findings of elevated omission and/or commission errors on measures of sustained attention (e.g., Continuous Performance Test) suggests that it is still unclear whether omission and/or commission errors are problematic for adults with ADHD and further highlights the need to study the relationship between cognitive performance and ADHD behavioral symptoms. No study to date has used both objective measures of activity from multiple locations (e.g., hands and feet) and measures of inattention through behavioral observations in an adult ADHD sample. Further, high precision actigraphs worn on the ankles and non-dominant wrist capture hand/feet movement and may improve upon the use of subjective rating scales and other measures (e.g., infrared motion analysis) employed by previous studies that measure activity level in adult ADHD samples.

Although the research examining the relationship between hyperactivity and attention in adult with ADHD is limited, the child ADHD research suggests that ADHD symptoms are associated strongly with poor cognitive performance on tasks of sustained attention (d = 1.19), auditory working memory (d = 0.69), visual-spatial working memory (d = 0.74) and visual problem solving (d = 0.83) (Kasper, Alderson, & Hudec, 2012; Raiker, Rapport, Kofler, & Sarver, 2012). A study examining objectively measured activity level during cognitive tasks found that the increased activity level experienced by children with ADHD was fully attenuated after controlling for between-group differences in working memory performance. Specifically, isolating working memory components revealed that the central executive processes (i.e., attentional controller), rather than the storage/rehearsal processes contributed to this relationship (SE = 0.60; Rapport et al., 2009). This further highlights the importance of examining the extent to which attentional processes mediate the relationship between ADHD symptoms and task performance.

Understanding the relationship between cognitive impairments and ADHD symptoms is critical, as cognitive impairments are associated with a variety of difficulties in daily living and have been well established for adults with ADHD (Barkley, 2006). Cognitive impairments, including deficits in working memory and sustained attention are associated with numerous functional deficits, including difficulties with planning, thinking flexibility, abstract thinking, and deficits in behavioral control (Alloway, Gathercole, Kirkwood & Elliot, 2009; Banich, 2009; Barkley, 2006). These abilities are related to a variety of areas of daily life functioning, including learning (Alloway, Gathercole, Kirkwood & Elliot, 2009), obesity (Gunstand, Paul, Cohen, Spitznagel, & Gordon, 2007), and occupational functioning (Barkley & Murphey, 2010). A greater understanding of the relationship between cognitive impairments and behavioral symptoms may inform the development of impairment-specific interventions for adults diagnosed with ADHD.

Inattention and ADHD

Research examining attentional processes in ADHD samples relies heavily on subjective measures such as self-report rating scales and/or questionnaires (Barkley, 2008). Notably, omission errors are related to inattention ratings and positive inter-correlations are found among all Continuous Performance Test measures (i.e., reaction time, omission and commission errors (Avisar & Shalev, 2011). Subjective ratings of attention are administered quickly and may be less expensive and more cost effective relative to behavioral observations. Adults with ADHD, however, may not provide an accurate assessment of their own symptoms (e.g., inattention, impulsivity) and may underreport their symptoms and the extent to which symptoms interfere with their ability to function (Kooij et al., 2008).

Behavioral observations may provide a more accurate and systematic way of understanding inattentive behavior (Rapport et al., 2009). Kofler and colleagues (2008) compared objectively measured inattentive behavior during cognitive testing with teacher ratings of inattention at school using teacher ratings; they found significant negative correlations between the two ($r = -0.40$ to -0.46, all $ps < 0.05$). Thus suggesting incongruence between teachers reported inattentive behavior and the child's objectively measured inattention, possibly due to difficulties with teacher's retrospective recall, halo effects, and/or rater expectation bias (Harris & Lahey, 1982; McClellen & Werry, 2000).

Using behavioral observation of attentive behavior in the classroom, Rapport and colleagues (2009) found that children with ADHD were inattentive for longer periods of time and switched between attention states (i.e., attentive and inattentive) more frequently. In a meta-analytic review of children with ADHD and their classroom inattentiveness, children with ADHD were more variable in their visual attention to task to their classwork relative to typically developing peers (Kofler, Rapport, & Alderson, 2008). Children with ADHD were on task 75% of the time relative to 88% of on task time for typically developing children (Kofler, Rapport, & Alderson, 2008). Children with ADHD also have a deficit in sustained attention to task to required stimuli during a computerized Continuous Performance Test (Börger & Van der Meere, 2000). Omission errors were examined as a function of visual attention to task. Children with ADHD looked away from the computer monitor more frequently for longer period of time, and the duration and frequency of the inattentive behavior increased with time spent participating in the task. The frequency and duration of looking away from the computer monitor during the Continuous Performance Test were strongly associated with omission errors (Börger & Van der Meere, 2000). The deficits of visual attention to task, as assessed by behavioral observations and behavioral coding, and the relationship between visual attention to task and cognitive performance, has yet to be examined in an adult ADHD sample.

ADHD and Co-occurring Internalizing Disorders

ADHD and depression commonly co-occur together, with rates of comorbidity ranging from 9% and 50% (Biederman et al., 2008; Kessler et al., 2006; Torgersen et al., 2006). Anxiety disorders are also known to frequently co-occur with ADHD, with rates of comorbidity up to 47% (Kessler et al., 2006). Neuropsychological research suggests that depression shares similar cognitive impairments with ADHD, specifically deficits in working memory and episodic memory (McDermott & Ebmeier, 2009), sustained attention (Porter et al., 2007), and processing speed (Andersson, Lovdahl, & Malt, 2010; Wilcutt, Pennington, Olson, Chhabildas, & Hulslander, 2005). Further, anxiety and ADHD also share common cognitive deficits. Eysneck and colleagues (2007) recently reviewed the cognitive deficits associated with anxiety, which include processing efficiency, working memory, and overall deficits in executive functioning. Studies have also examined the effects of depression on response inhibition (e.g., a measure of hyperactivity/impulsivity) and found increased rates of commission errors and response inhibition deficits (Kaiser, Unger, Kiefer, Markela, Mundt, & Weisbrod, 2003). Although the DSM-5 cites physiological symptoms for depression, such as psychomotor agitation (e.g., inability to sit still, hand wringing), studies that have examined objective measures of activity level found decreased rates of activity level in individuals who had high ratings of depression (Mendlowicz, Jean-Louis, Gizycki, Zizi, & Nunes, 1999; Teicher, 1995; Volkers et al., 2003).

Research examining objective measures of activity level in individuals with anxiety is much more limited. Studies have examined the sleep patterns of adults with anxiety in standard instances, as well as situational stress-inducing conditions (e.g., sleep before surgery), and found increased rates of activity during sleep, and less efficient sleep (e.g., more awakenings). Thus far, the extent to which objectively measured activity level is associated with anxiety is unclear. Given the elevated rates of activity during sleep, and the physiological symptoms endorsed in the DSM-5 (American Psychological Association, 2013) it may be that individuals with anxiety move more than individuals without anxiety disorders.

Chapter 3

The Present Study

The present study aims to examine the extent to which visual attention to task and activity level are related to performance on a sustained attention task. High precision actigraphs worn on the ankles and non-dominant wrist capture hand/feet movement, and behavioral codes of visual attention to task (e.g., participants looking behavior during a computerized task) are used to examine differences in objectively measured attention and activity level during control conditions and a sustained attention task. The present study will extend previous work by controlling for current anxiety and depression severity. The current study hypothesizes that individuals with ADHD will exhibit elevated activity level rates compared to the comparison group during the control conditions and sustained attention task (hypothesis 1a). The current study also hypothesizes that both groups will exhibit higher activity level rates during the Continuous Performance Test (CPT) relative to the control conditions (hypothesis 1b). After controlling for anxiety and depression severity, activity level is expected to remain elevated for adults with ADHD during the CPT and control conditions (hypothesis 1c). Relative to the comparison group, individuals with ADHD are expected to make more omission, commission and total errors on a sustained attention task (hypothesis 2). Finally, individuals with ADHD are expected to exhibit decreased visual attention to task relative to a comparison group (hypothesis 3).

The second aim of the current study is to examine the extent to which visual attention to task mediates the relationship between activity level and total errors on a sustained attention task. The relationship between hyperactivity and attention (see Fig 1; Pathway A) can be found in both the child and adult ADHD literature. In a study examining ADHD in adults, the combination of attention and activity level was best able to discriminate ADHD individuals from controls (Teicher et al. 2012). The relationship between attentional processes and cognitive performance is also well documented (see Fig 1; Pathway B). In a meta-analysis on 24 articles examining adult ADHD functioning in neuropsychological domains, Schoechlin and colleagues (2005) found moderate between-group effect sizes for focused attention ($d = .55$) and sustained attention ($d = .52$) during cognitive tasks. A relationship between hyperactivity and cognitive performance (see Fig 1, Pathway C) is also found in adults with ADHD. A study examining the effects of limb movement on cognitive performance in a non-clinical population found that increased activity interfered with cognitive performance on a working memory task (Lawrence, Myerson, Oonk, & Abrams, 2001). The current study hypothesizes a positive relationship between objectively measured activity level and inattention (hypothesis 4a), errors on a sustained attention task and objectively measured activity level (hypothesis 4b) and inattention and errors on a sustained attention task (hypothesis 4c). Further, the current study predicts that attention will fully mediate the relationship between hyperactivity and total errors on a sustained attention task (hypothesis 4d). The current study also seeks to replicate and expand on existing literature by conducting secondary, exploratory, meditational analysis to understand the extent to which the omission and/or commission errors influence the relationship between hyperactivity and visual attention to task. Hypotheses for the exploratory analyses are not provided due to limited and inconsistent research on the topic.

Chapter 4

Methods

Participants

Adults aged 18 to 60, diagnosed with ADHD (n = 15) and adults with sub-clinical ADHD symptoms (n = 17) participated in the study. The systematic recruitment plan included the following: (1) the IRB-approved advertisements recruiting individuals with attention problems and healthy controls were posted on General Bulletin Boards at the University of Tennessee; (2) a brief description of the study and the IRB-approved advertisement was posted on the Behavior and Learning Lab's website (http://utkbehaviorandlearninglab.org); (3) a brief description of the study and IRB-approved advertisement was posted on the University of Tennessee Sona System website (4) IRB-approved advertisements were made available to individuals who attended ADHD educational seminars conducted by the research team; and (5) IRB-approved advertisements were posted on community bulletin boards with prior approval from appropriate departments and/or administrators.

Due to the task demands of the study, exclusion criteria for the study included gross neurological, sensory or serious motor impairment or a history of seizure disorder or psychosis. Individuals were also excluded if they were prescribed/using psychotropic medication or using medications that might affect physiological measurement (e.g., benzodiazepines, beta blockers). Individuals who were prescribed psychostimulants were asked to refrain from taking their medication at the time of testing. Finally, individuals who were unable to complete the assessment in the lab were excluded. However, no participants met these exclusion criteria for the current study. Individuals with comorbid disorders (e.g., depression, alcohol use disorders) were included in the current study if they did not meet any other exclusion criteria (see Table 2 for comorbid disorders).

Group Assignments

Participants included in the ADHD group met the following criteria, based on the Barkley Adult ADHD Rating Scale (BAARS-IV): (1) a total ADHD index score at or above the clinical range (e.g., 93rd percentile) based on self-report of current symptoms, *or* other-report of six or more symptoms; and (2) a total ADHD index score at or above the clinical range (e.g., 93rd percentile) based on self-report of childhood symptoms, *or* other-report of six or more childhood symptoms. Symptoms must be present in two or more settings.

Individuals included in the comparison group met at least one of the following criteria, based on the Barkley Adult ADHD Rating Scale (BAARS-IV): (1) A total ADHD index score below the clinical range (e.g., 93rd percentile) based on self – report of current symptoms, *or* other-report of less than six symptoms; and (2) A total ADHD index score below the clinical range (e.g., 93rd percentile) based on self-report of childhood symptoms *or* other-report of less than six childhood symptoms.

Procedures

The current study is part of a larger study examining ADHD-related cognitive and behavioral processes. Individuals interested in learning more about the study were instructed to contact the lab to complete a telephone screen to determine study eligibility. The telephone screen consisted of a brief review of demographic and contact information and administration of the Adult Self-Report ADHD Rating Scale (ASRS).

The experimental tasks were administered as part of a larger battery of laboratory-based tests that required the participant's presence for approximately two hours for three sessions. Upon arrival of each participant at the laboratory, the experimenter reviewed and obtained written consent to participate in the session, and then attached the actigraphs (i.e., a small, watch-like device to measure activity level) on the participant. At the beginning of the first session, all participants were administered the MINI and the WASI. Participants also received self –report measures to fill out and return to the laboratory on their next session.

To compensate for time required to participate in this study, improve response rate, and decrease attrition, participants earned a $10 Wal-Mart gift card for each session (Note: the study consisted of three, two-hour sessions) and a $5 Wal-Mart gift card for completing self-report measures.

Measures

*Clinical interview***.** All participants were administered a detailed, structured neuropsychological interview using the Mini International Neuropsychiatric Interview (M.I.N.I), which assessed onset, duration, severity, and impairment of current and past episodes of psychopathology in adults based on the on DSM-IV criteria. The specificity for all diagnoses of the MINI ranges from .72 to .97, and inter-rater reliability is high with kappa coefficients ranging from .88 to 1.0 (Sheehan et al., 1998).

Adult ADHD Self-Report Scale (ASRS). The ASRS was designed by the World Health Organization and researchers at both New York University Medical School and Harvard Medical School; the ASRS part A is a six-item, self-report measure of attention problems in adults (see Appendix A; Kessler et al., 2005). The widely used measure provides a five-item Likert scale for participants to rate how often they have engaged in the described behaviors over the past six months (Kessler et al., 2005). Scores are calculated by adding the number of responses marked 3 ("sometimes") or higher for questions 1 – 3, and 4 ("often") or higher for questions 4 – 6. A positive ADHD screen is defined as a score of four or more on Part A of the measure (positive predictive value ≥ .57%). Research for the six-item measure has documented high internal consistency (r = 0.63 – 0.72), as well as test-retest reliability (r = 0.58- 0.77; Kessler et al., 2007).

Barkley Adult ADHD Rating Scale (BAARS-IV). The Barkley report forms (Current Symptoms Scale – Self Report and Other Report, Childhood Symptoms Scale – Self Report and Other Report; See Appendix B-E, respectively) are widely used to assess ADHD symptoms (Barkley, 2011). The Barkley Adult ADHD Rating Scale (BAARS-IV) has shown high internal consistency (.92 for current ADHD and .95 for childhood ADHD), good inter-observer agreement (.67 to .70), and high test-retest reliability (.75). The BAARS-IV has also been shown to have high correlations with other measures of ADHD symptoms (Barkley, 2011). Clinically significant cutoff scores for BAARS-IV self-report form is typically defined as total scores and/or symptom counts that are at the 93rd percentile or higher on each subscale (e.g., inattention, hyperactivity/impulsivity), and are utilized in the current study. Self-report forms were completed by each participant; other-report forms were given to the participant, the participant then shared the measures including directions with someone who has knowledge of their functioning prior to age 12 for the childhood report, and someone who was able to report on their current functioning (Barkley, 2011). Norms are unavailable for the other-report forms due to the high-degree of difficulty to obtain norms from each possible reporter (e.g., mother, siblings, aunts, significant others; Barkley, 2011). Therefore, in the current study, a symptom count of six or more symptoms on the other-form, as required by the DSM-IV to meet criteria for an ADHD diagnosis, was used as the clinical cut off point for inclusion in the ADHD group.

Beck Depression Inventory-2 (BDI-II). The BDI-II is a 21-item self-report measure of the severity of depression symptoms, and instructs the participants to endorse the presence of each symptom using a 4-point likert scale ranging from 0, *"symptom is not present"* to 3 *"symptom is interfering with daily life."* Higher scores on the BDI-II denote higher rates of depression symptoms. The measure has a high one-week test-retest reliability (r = .93) and high internal consistency (α = .92) in a clinical outpatient sample (Beck, Steer, Ball, & Ranieri, 1996), and in a college population (α = .89; Steer & Clark, 1997).

Beck Anxiety Inventory (BAI). The BAI is a 21-item self-report measure of the severity of anxiety symptoms, which instructs participants to evaluate how bothersome each statement is to them using a 4-point likert scale ranging from 0 "*not at all*" to 3 "*severely*." High scores on the BAI denote higher rates of anxiety symptoms. The measure has high internal consistency (α = .92) in outpatients (Steer, Ball, Ranieri, & Beck, 1997), and one-week test-retest reliability of .75 (Fydrich, Dowdall, & Chambless, 1992)

*Intellectual functioning***.** The Wechsler Abbreviated Scale of Intelligence Second Edition (WASI-II; Wechsler, 1999) was administered to all participants to determine IQ functioning. The standardization of the WASI–II was conducted from January 2010 to May 2011 on a nationally representative sample of approximately 2,300 individuals aged 6–90, and has evidence of both concurrent validity with other IQ measures (Hays, Reas, & Shaw, 2002) and construct validity (Canivez, Konold, Collins, & Wilson, 2009). The WASI-II yields an FSIQ-2 score, which is an estimate of general cognitive ability from the performance on two-subtests of the WAIS-IV (i.e., vocabulary and matrix reasoning).

Sustained Attention. The CPT is a computer-based task that is designed to assess sustained attention and impulsivity. Outcome measures include omission errors (i.e., failing to identify the target stimulus), commission errors (i.e., identifying a non-target), and perseverative errors (i.e., repetition of a previous error/response). The task is comprised of three, three-minutes blocks resulting in a total of nine minutes to complete the task. 180 letters (33.3%) were targets (i.e., double – letters; 90 total responses) and the remaining 360 (66.7%) were non-targets. Participants were instructed to press the left mouse button every time a letter repeated itself, and were told to inhibit their response to all other letters. In terms of diagnostic utility for adults with ADHD, versions of the CPT have been shown to have a sensitivity coefficient of 55.0%, and specificity coefficient of 76.4% (Epstein, Conners, Sitarenios, & Erhardt, 1998). The current study utilized a composite score of total errors (i.e., a sum of omission, commission, and perseveration errors) across the three blocks. Split-half reliability analyses were conducted in SPSS to examine the internal consistency of the version of the CPT used in the current study. Specifically, split-half for total errors between block one, block two, and block three were examined. To adjust the split-half correlation, the Spearman-Brown formula was utilized (Halperin, Sharma, Greenblatt, & Schwartz, 1991). Spearman (1910) and Brown (1910) defined the split-half reliability as the correlation between two halves of a test, corrected to full test length by the Spearman-Brown prophecy formula. The split-half correlation coefficient showed acceptable levels of reliability (.90).

Control Condition. Activity level and visual attention to task were assessed while participants used the Microsoft® Paint program for five minutes at the beginning (i.e., C1) and end (i.e., C2) of each experimental session. The Paint program served as control conditions to assess and control for within-day fluctuations in activity level and visual attention to task. The three pre and three post activity level control conditions were averaged separately to create pre and post composite scores.

Activity Level. Activity level was assessed using MicroMini Motionlogger® actigraphs. The reliability for actigraphy is estimated to be between .90 and .99 (Tryon, 1985). Actigraphs are superior at differentiating between children with ADHD, typically developing children, and children with other psychopathological disorders compared to parent and teacher reports (Rapport et al., 2006). Actigraphy research has also found differences (e.g., increased rates of activity level) in adults with ADHD compared to healthy controls both during daytime hours and sleep (Boonstra, Kooij, Oosterlaan, Sergeant, Buitelaar, & Van Someren, 2007). Actigraphs are acceleration-sensitive devices that sample motor activity (Ambulatory Monitoring, 2004), in order to measure the intensity of movements, the actigraphs were set to Proportional

Integrating Measure (low-PIM) mode, which allows measurement of the frequency, duration, and intensity of movements. The actigraphs sample motoric movements 16 times per second (16 Hz) and are collapsed into 1- minute epochs. Actigraphy values range from 0 (no movement) to 65,535. Data is downloaded through a hardware interface and is analyzed using the Action- W2 software program (Ambulatory Monitoring, 2004). The participants wore the actigraphs on their non-dominant hand, left and right ankle to measure activity level. A total extremities score (TES) was calculated by taking the mean from each site (i.e., non-dominant hand, left foot, right foot), and averaging them together for each task (e.g., control conditions, CPT). A total of one participant within the comparison group was missing data due to errors with the actigraphy devices (e.g., battery malfunction). Mean substitution was utilized for outlying data points in averaging pre and post control condition TES scores for three participants in the ADHD group, and six participants in the comparison group.

Observed visual attention to task. A fixed digital camera in the assessment room was used to record behavior while the participants sat in a chair and completed the various computer tasks. Observations were subsequently coded using the Noldus Observation System. Two behavioral coders, blind to diagnostic status, coded for orientation to task behavior using the Noldus Observation System (Noldus Information Technology, 2011). Participants were coded as oriented to task if their head was directed within 45° vertical/horizontal tilt for more than two consecutive seconds. Participants were coded as not oriented to the task if the participants head exceeded a 45° vertical/horizontal tilt for more than two consecutive seconds. Behavior was coded using a continuous observation scheme. The *oriented* and *not* *oriented* are analogous to on-and off – task definitions used in most laboratory and classroom observation studies (Kofler et al., 2008). Research assistants obtained a minimum 80% agreement compared to a gold standard practice tape as a requirement to coding participants. Inter-rater reliability was tested for all observation days using Cohen's Kappa (K), K = Pr(a) – Pr(e)/1-Pr(e), where Pr(a) is observed percentage of agreement, and Pr(e) is expected percentage of agreement. Kappa has a range from 0 – 1.00, with larger values indicating greater reliability. Inter-rater reliability was above satisfactory (i.e., K = .70) for all conditions, with raters reaching at least .85 for both control conditions, and the CPT task.

Chapter 5

Results

Data Screening and Outliers

All variables were tested for outliers within each group (e.g., ADHD group, comparison group). Based on procedures for identifying univariate outliers by Tabachnick and Fidell (2013), data points falling 2.5 standard deviations above the mean, given the small sample size, were identified as outliers. One outlier within the ADHD group and two outliers within the comparison group were identified for variables pertaining to activity level during the CPT (e.g., mean activity level score for each extremity). One outlier within the ADHD group and one participant with outliers within the comparison group were identified for total errors on the CPT, across the three blocks of the CPT (e.g., 3-3 minute blocks). One participant within the ADHD group was identified as an outlier for BDI-II total score, and one participant within the comparison group was identified as an outlier for BAI total score. Given the small sample size, mean substitution (within each group) was utilized for significant outliers as described by Tabachnick and Fidell (2013).

Participant Characteristics

Participant characteristics are presented in Table 1; *t*-tests and Chi-Square analyses were conducted to examine between-group differences in demographic information, ADHD symptoms, and current ratings of depression and anxiety severity. The groups differed on prescription of stimulation medication, χ^2 (1, N = 29) = 8.19, p = .006. The ADHD group was more likely to be prescribed stimulant medication. No other significant between-group differences were found in regards to demographic information, including age (ADHD, *M* = 26.93, *SD* = 9.02; Control, *M* = 28.56, *SD* = 11.23), and FSIQ-2 scores (ADHD, *M* = 107.93, *SD* = 16.31; Control, *M* =111.81, *SD* = 11.21). Comorbid disorders as assessed by the MINI are presented in Table 2. Means, standard deviations, and results of the *t*-tests for self-report and other-report for current and childhood ADHD symptoms on the BAARS-IV are presented Table 3. As expected, the groups differed significantly on self-report of current and childhood inattention, hyperactivity and total scores (all *p*'s $< .05$), with the ADHD group exhibiting higher scores in all domains. For other-report on the BAARS-IV, the groups differed significantly on the childhood inattention, hyperactivity, and total scores (all *p*'s $< .05$), again with the ADHD group having higher scores. However, groups did not differ on the other –report of current inattention, hyperactivity, or total scores (all *p*'s $>.05$; Table 3). On the ASRS, the groups significantly differed on total symptom count, with the ADHD group reporting more symptoms than the community controls (Table 3).

Groups were not significantly different on ratings of current depression severity as measured by the BDI-II (ADHD, *M* = 11.64, *SD* = 8.08; Control, *M* = 10.60, *SD* = 9.82), $t(26) = 0.30$, $p = .77$. Groups were significantly different on current anxiety severity as measured by the BAI (ADHD, *M* = 13.15, *SD* = 5.91; Control, *M* = 5.30, *SD* = 4.92), $t(26) = 3.84$, $p = .001$, with the ADHD group having higher current anxiety severity ratings (Table 3)[1]. Due to the significant

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[1] Groups did not differ significantly on the BAI prior to data cleaning for outliers, (ADHD, *M* = 13.15, *SD* = 5.91; Control, *M* = 7.40, *SD* = 9.86), $t(26) = -1.83$, $p = .08$.

difference between groups in anxiety severity ratings, and comorbid anxiety disorders and mood disorders assessed by the MINI (see Table 2), current anxiety and depression severity, as measured by the BAI and BDI-II, were included as covariates for analyses examining activity level in order to examine the unique contribution of ADHD diagnosis on activity level.

Tier 1: Between and within-group differences in activity level, task performance, and attention

Activity level. To examine between and within group differences in activity level rates, a 2 (Group: ADHD, comparison group) x 3 (Activity level during tasks: C1, CPT, C2) mixed-model Analysis of Variance (ANOVA) was conducted, with activity level during tasks as the within-subjects factor and group as the between-subjects factor. Significant main effects were followed up with LSD adjusted pairwise comparisons, significant interactions were followed up with repeated measures ANOVAs and independent samples t-tests. Means, standard deviations, and Cohen's d effect sizes are presented in Table 4; estimated marginal means and standard errors are presented in Table 5. There was a significant main effect of activity level during the tasks, $F(1.35, 32.37) = 5.12$, $p = .021$, across groups activity level during the tasks differed significantly. There was significant group by condition interaction, $F(1.35,32.37) = 9.97$, $p = .002$, activity level during the tasks differed significantly by group. Within the comparison group, there was a significant main effect of activity level during task, $F(2,26)=20.77$, $p < .001$, activity level differed significantly during the tasks. LSD adjusted pairwise comparisons indicated a significant difference between C1 and C2 ($p = .001$), the CPT and C2 ($p < .001$), but no difference between C1 and the CPT ($p = .624$) for the comparison group. This finding suggests that the comparison group moved significantly more during C2 relative to both C1 and the CPT. Within the ADHD group, there was a main effect of activity level during tasks, F(1.19, 13.09) = 5.46, p = .031, activity level differed significantly during the tasks. LSD adjusted pairwise comparisons indicate a significant difference between C1 and the CPT (p= .023), but no difference between C1 and C3 (p = .122), and the CPT and C2 (p = .064) for the ADHD group. This finding indicates that the ADHD group moved significantly more during the CPT relative to the control conditions.

Tests of between-subjects effects indicated a significant main effect of group, $F(1,24) = 6.40$, $p = .018$; with the ADHD group having higher rates of activity level. To further explore the main effect of group, an independent samples t-test was conducted. The ADHD and comparison group differed significantly in activity level during the CPT $t(12.40) = 2.96$, $p = .012$, with the ADHD group moving significantly more. There were no significant differences between the groups in activity level during C1, $t(17.86) = 1.84$, $p = .083$, or C2, $t(29) = 0.29$, $p = .772$ (Table 4). Overall, the ADHD group moved significantly more during the CPT relative to the comparison group.

Next, a 2 (Group: ADHD, comparison group) x 3 (Activity level during tasks: C1, CPT, C2) mixed Analysis of Covariance (ANCOVA), was conducted to examine if activity level during the tasks varied as a function of current ratings of anxiety and depression severity, as determined by the total scores of the BAI, and BDI-II, respectively (Table 3 for means and standard deviations). After accounting for the variance in activity level associated with BAI and BDI-II scores, the main effect of activity level during tasks was no longer significant $F(1.37, 30.04) =$

0.567, p =.509. However, the group (e.g., ADHD versus comparison) by activity level during tasks interaction remained significant, F (1.37, 30.04) = 5.75, p = .015. Post-hoc tests of between-subjects effects found that the difference between the groups in activity level during the tasks did not vary as a function of BAI, F(1, 22) = .000, p =.989, or BDI-II scores, F(1, 22) = 0.348, p =.561[2].

Task performance. An independent samples t-test was conducted to examine between-group differences in performance on the CPT. There was not a statistically significant difference between the ADHD group and comparison group on the CPT, t(13.99) = 1.91, p = .077, d = .78; however, Cohen's *d* revealed a large effect size (Table 4)[3].

Visual attention to task. A series of independent samples t-tests were conducted to examine between-group differences in visual attention to task during the control conditions, and the CPT. There were no significant differences between the ADHD group and comparison group in percent of time spent on task during the control conditions, t(29) = 0.90, p = .371. There was no difference between the ADHD group and comparison group in percent of time spent on task during the CPT; both groups were on task 100% of the time during the CPT (M=100.00, SD = 0; Table 4).

Tier II: Meditational Analyses

Bivariate correlational analyses were conducted to (1) examine the relationship magnitude and direction among study variables and (2) determine if meditational analyses

[2] Results were not significantly different prior to data cleaning for outliers.
[3] Results were not significantly different prior to data cleaning for outliers.

were justified. Bivariate correlations revealed that activity level during the CPT and total errors on the CPT were significantly correlated, $r(25) = .44$, $p = .032$, (Table 6). Correlational analyses for percent on task during the CPT with either activity level during the CPT or total errors on the CPT were unable to be conducted due to the classification of percent on task as a constant variable (i.e., 100%). There are four steps to establish mediation; the first two steps require that the variables (e.g., causal variable *Y*, outcome variable *X*, and meditator variable *M*) in the meditational model be correlated with each other (Preacher & Hayes, 2004; Preacher & Hayes, 2008). Since the proposed mediator variable (i.e., percent of time on task) was not correlated with the outcome variable (i.e., total errors on the CPT), meditational analyses were not justified.

Chapter 6

Discussion

The purpose of the current study was to examine differences between individuals with ADHD and a comparison group on a task of sustained attention (i.e., CPT), activity level, and visual attention to task. The study expands on previous research by utilizing objective measures of both attention and activity level during a sustained attention task.

Activity level did not differ between the groups (e.g., ADHD and comparison groups) during C1 and C2; however, the ADHD group showed significantly higher activity level rates during the CPT, partially supporting hypothesis 1a. Specifically, the between-group effect size for the current study (d =1.20) for differences in activity level is comparable to findings that of both Teichler and colleagues (d = 1.60; 2013), and Lis and colleagues (d = 1.20; 2010), who also utilized objective measures of activity level. These findings are also congruent with studies examining activity level in childhood. Alderson and colleagues (2011) found that children with ADHD were significantly more active during a cognitive task (i.e., stop-signal task); however, there were no differences between the ADHD and comparison groups in activity level during the control conditions after controlling for attentional processes. Further, results also partially support hypothesis 1b, where the ADHD group moved significantly more during the CPT relative to the C1; however, the comparison group did not move significantly more during the CPT, and was more active during C2. This is consistent with previous research documenting increased rates of objectively measured activity level in adults with ADHD during cognitive testing (Lis et al., 2010; Teicher et al., 2013). The present findings also support this pattern of activity level in adults with ADHD, with the ADHD group moving more during cognitive tasks, but not control tasks.

The findings of the current study support hypothesis 1b of increased rates of activity level in adults with ADHD, and further documents that adults diagnosed with ADHD exhibit higher activity level rates during cognitive tasks when objective measures are utilized. Our findings, and previous research that has utilized objective measures of activity level, differ from studies that examine subjectively measured hyperactivity. Kessler and colleagues (2010) found that while 94.9% of adults continued to meet criteria for the inattentive symptoms of ADHD, only 34.6% continued to meet criteria for the hyperactive symptoms. While studies examining subjective vs. objective measures may differ in findings, the current study's subjective rates of inattention and hyperactivity are comparable to previous studies examining subjective measures. Adults in the ADHD group reported higher rates of inattention symptoms relative to hyperactive symptoms in the current study, similar to the findings of Kessler and colleagues (2010). Despite the decreased self-report of hyperactive symptoms in the current study and previous research (Kessler et al, 2010), the fidgeting and movement assessed by objective measures show support for the presence of hyperactivity symptoms in adults, at least during cognitive testing. Further, the current diagnostic criteria for hyperactive symptoms in adult ADHD may not fully capture the behavioral symptoms that these individuals are experiencing; examining behaviors such as fidgeting and utilizing objective assessment through actigraphy may capture the persistence of hyperactive behavior exhibited by adults with ADHD.

This study also attempted to understand the extent to which anxiety and depression symptoms are associated with activity level during a cognitive task. After accounting for current depression and anxiety severity, activity level was significantly higher for the ADHD group than for the comparison group, which supports hypothesis 1c of the study. Although ADHD is often comorbid with anxiety (up to 47%; Kessler et al., 2006) and depression (up to 50%; Kessler et al., 2006), and despite high rates of comorbidity within the current sample, current depression and anxiety severity did not account for the elevated activity level in the ADHD group. Further, current depression and anxiety severity ratings did not individually impact activity level during cognitive tasks. Research utilizing actigraphy with adults with depression have found decreased motor movement compared to controls (Mendlowicz, et al., 1999; Teicher, 1995; Volkers et al., 2003). To our knowledge, no study has examined the activity level of adults with anxiety disorders during the daytime hours. The DSM-5 suggests that individuals with depression or anxiety experience increased feelings of psychomotor agitation; however, these symptoms of motor agitation may be inherently different than the movement assessed by objective measures in adults with ADHD (American Psychological Association, 2013). For example, feelings of restlessness or inability to sit still could be more of an internalized state than an observable behavior that can be measured, especially when compared to the hyperactive behavior exhibited by adults with ADHD. Further, the physical symptoms of anxiety, such as feelings of “restless or being keyed up”, maybe also be just that, *feelings,* rather than overt behavior (American Psychological Association, 2013). Still, for individuals with ADHD, current depression and anxiety symptom severity does not account for the increased activity level during cognitive tasks.

In the current study, there were no statistically significant between-group differences in total errors on the CPT, which does not support hypothesis 2. However, the ADHD group in the current study did have over two-times more errors than the comparison group, and large effect size (*d* = .78) was found between the groups. Further, it is possible that with a larger sample, and more statistical power as determined by the post-hoc power analyses (e.g., N = 44), this pattern would become significant. Nevertheless, the insignificant finding is inconsistent with previous studies that have found significant differences in CPT performance (Avisar & Shaley, 2011; Jones, Craver, Lemley, & Barrett, 2008; Lis et al., 2010). Meta-analyses examining neuropsychological functioning in adults with ADHD have also found significant differences between typical controls and adults with ADHD in attention, as measured by performance on the CPT (Hervey, Epstein, & Curry, 2004; Schoechlin & Engel, 2005).

Overall, the majority of the existing literature has found deficits in attention for adults with ADHD as measured by the CPT, which is inconsistent with the findings from the current study. However, the majority of the studies examining CPT performance have compared adults with ADHD to healthy controls without any co-occurring mental health disorders. A recent meta-analysis of neuropsychological performance of adults with ADHD only had 7 out of 33 studies that utilized a clinical comparison group (Hervey, Epstein & Curry, 2004). The current study utilized a comparison group with a range of psychological functioning. The unique psychological make-up of the current study's comparison group could contribute to the lack of significant differences between the groups in CPT performance. The comparison group has moderate rates of depression and anxiety, both of which are associated with deficits in attention, which in-turn could effect performance on the CPT. Another area for consideration is the variation in administration time differences between the numerous versions of the CPT. Studies have found more significant differences in adults with ADHD on versions of the CPT that were longer in duration (Fischer, Barkley, Smallish, & Fletcher, 2005; Malloy-Diniz, Leite, Correa & Bechara, 2007); future studies may want to utilize a longer version of the CPT, such as the Conner's continuous performance test, which takes approximately 20 minutes to complete, while objectively measuring activity level. The CPT used in the current study was approximately nine minutes in total; it may be the case that adults with ADHD could show more robust performance deficits during a CPT with a longer administration time requiring more effort and sustained attention.

The ADHD group and comparison groups did not differ on the objective measure of inattention (e.g., visual attention to task); both groups were oriented to the CPT 100% of the time of administration. These results also did not support hypothesis 3 of the study. Further, post-hoc analyses revealed the current study had limited statistical power to identify differences between the groups for visual attention to task, given the high rates of orientation to task for both groups. Yet, to a certain degree these findings are in line with other adult studies (Teichler et al., 2012) that have found larger effect sizes for activity level (i.e., shin movements, Cohen's d = 1.05), compared to attention variables computed from performance on a cognitive task (i.e., time spent fully attentive, Cohen's d = 87). However, these results differ from previous child research showing that individuals with ADHD are visually inattentive more frequently, and for longer durations, when compared to their typically developing peers during computerized sustained attention tasks, and in school environments (Börger & Van der Meere, 2000; Kofler et al., 2008). Further, these studies utilized observational methods of visual attention to task, and had similar definitions to on- and off-task behavior. Although overt inattention and hyperactive symptoms are evident in childhood, adults with ADHD may experience the same difficulties with inattention and increased activity level, but not to the extent that is easily observed in behavioral observations, and may require more objective and sensitive measures to be identified.

No study to date has examined visual attention to task through behavioral coding with adults with ADHD; therefore, these results contribute to the existing literature by examining whether visual inattention was contributing to performance on the CPT. Since the ADHD group was visually attentive to the CPT, differences in task performance cannot be explained by overt visual inattention. This suggests that increased errors on sustained attention task are more likely due to physiological and/ or neuropsychological factors associated with ADHD, such as sustained attention, focus of attention, or visual processing speed rather than mere behavioral symptoms.

Clinically, these findings have a potential impact on the assessment and diagnostic evaluations conducted on adults with ADHD. Given that activity level has been shown to have the largest effect size (d = 1.20), clinicians may find it more diagnostically informative to examine fidgeting and activity level through objective measure rather than self-report measures, which have been shown to be unreliable in ADHD samples (Fischer & Barkley, 2007). Further, the current study found no between-group differences in overt attention, suggesting that unlike ADHD in childhood, adults with the disorder may not be as overtly distractible or inattentive. Although no significant differences were found on cognitive performance during the CPT, likely due to a lack of statistical power, adults with ADHD still had two-times more errors on the CPT and a large effect size between groups (Cohen's d = .78). It also could be the case that adults with ADHD do not present clinically with as robust deficits in performance on cognitive tasks relative to children with ADHD.

Conclusions, Limitations, and Future Directions

The current study adds to extant research that has shed light on the continuation of hyperactive symptoms for adults with ADHD. Further, the findings support the notion that ADHD uniquely contributes to activity level during cognitive testing; depression and anxiety severity had no significant impact on the activity level of adults with ADHD. The current study has begun the process of examining behavioral inattentive symptoms, and their impact on cognitive performance. Future studies will need to examine the more subtle forms of inattention. The current study's definition of behavioral inattention (i.e., looking away from the computer monitor for two seconds) may not capture important and indirect inattentive behaviors that could be experienced by adults (e.g., closing their eyes, focus of attention). Since the findings of the current study suggest it is not overt behavioral inattention that is exhibited by adults with ADHD, future research could utilize eye-tracking methods to examine if the adults with ADHD are attentive to the screen during computerized tasks. Further, utilizing an assessment method that examines more subtle attentive behaviors could allow for testing the meditational model presented in the current study.

The main limitation of the current study is the small sample size. Future studies should attempt to examine the differences in attention, activity level, and cognitive performance in a larger sample of adults with ADHD. Increasing the power with a larger sample size would likely find significant differences between the ADHD and comparison group, where the current study only found differences that were statistical trends (i.e., total errors on the CPT). Specifically for variables in the CPT, post-hoc power analysis revealed that on the basis of the mean, given the between-groups comparison effect-size observed in the present study (d = .78), the power to detect a difference between groups was at the .60 level. A larger sample size (n = 44) would be needed to detect a difference at the recommended .80 level (Cohen, 1998). For the visual attention to task variable, post – hoc power analysis revealed that 4,328,871,422 participants would be needed to detect a significant difference between the groups. Another limitation of the current study comes from a possible lack of generalizability due to the homogenous sample. Future studies should examine these variables in a more ethnically and racially diverse sample. An area of this study that provides both a strength and a weakness is the high rates of comorbidities found within the sample. Although including individuals with comorbid disorders allows for a more generalizable sample, future studies may be warranted to examine differences between adults with ADHD and controls with limited or controlled comorbidities to examine the unique contribution of each disorder. Future studies should also seek to understand underlying neuropsychological factors (e.g., focus of attention, visual processing speed) related to performance on the CPT, since behaviorally assessed visual attention to task does not appear to be impacting performance.

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Appendix

Table 1. Participant Characteristics

	ADHD		Comparison	
	Mean	*SD*	Mean	*SD*
Age	26.93	9.02	28.56	11.23
Academic and Intellectual Functioning				
College GPA	2.94	.99	3.11	.36
FSIQ-2	107.93	16.31	111.81	11.21
	n	(%)	n	(%)
Gender				
Female	5	16.1%	8	25.8%
Male	10	32.3%	8	25.8%
Student and Employment Status				
Student	9	33.3%	5	18.5%
Employed	3	11.1%	7	25.9%
Unemployed	1	3.7%	2	7.4%
Ethnicity/Race				
Caucasian/White	13	44.8%	12	41.4%
African-American/Black	1	3.4%	0	0.0%
Hispanic/Latino	0	0.0%	1	3.4%
Other	0	0%	2	6.9%
Prescribed Stimulant Medication				
Yes	12	41.4%	5	17.2%

Note: Percentages calculated for entire sample

Table 2. Comorbid Disorders on the Mini International Neuropsychiatric Interview

	ADHD		Comparison	
	n	%	n	%
Major Depressive Episode	6	40%	3	18.75%
Past Major Depressive Episode	7	46.67%	4	25.00%
Lifetime Mood Disorder with Psychotic Features	1	6.67%	0	0.0%
Bipolar I with Psychotic Features	0	0.0%	1	6.25%
Bipolar II Disorder	1	6.67%	0	0.0%
Manic Episode	1	6.67%	0	0.0%
Past Manic Episode	0	0.0%	1	6.25%
Hypomanic Episode	1	6.67%	1	6.25%
Past Hypomanic Symptoms	1	6.67%	0	0.0%
Generalized Anxiety Disorder	1	6.67%	2	12.50%
Panic Disorder, Lifetime	0	0.0%	1	6.25%
Panic Disorder Limited Sx Attacks, Lifetime	1	6.67%	0	0.0%
Generalized Social Phobia	1	6.67%	0	0.0%
Obsessive-Compulsive Disorder	1	6.67%	1	6.25%
Post-Traumatic Stress Disorder	1	6.67%	0	0.0%
Alcohol Dependence	3	20.00%	2	12.50%
Alcohol Abuse	1	6.67%	2	12.50%
Non-Alcohol Substance Dependence	2	13.33%	1	6.25%
Non-Alcohol Substance Abuse	2	13.33%	2	12.50%
Poly-Substance Dependence	1	6.67%	0	0.0%
Anorexia Nervosa	0	0.0%	1	6.25%
Lifetime Antisocial Personality Disorder	0	0.0%	1	6.25%

Note: Percentages calculated for within-groups; Sx = symptoms

Table 3. Self and other-report of ADHD, anxiety and depression symptoms

	ADHD		Comparison		
BAARS-IV Self –Report Total Scores	Mean	*SD*	Mean	*SD*	*t*
Current inattention	25.33	5.26	20.69	6.84	2.10*
Current hyperactive	11.53	2.67	9.31	3.18	2.10*
Current total scores	48.47	9.81	37.13	11.11	3.00*
Childhood inattention	30.00	4.16	16.94	6.93	6.41*
Childhood hyperactive	26.80	5.11	15.50	6.28	5.47*
Childhood total score	55.79	7.28	32.43	12.66	6.29*
BAARS-IV Other-Report Total Scores					
Current inattention	20.09	9.06	15.27	4.92	1.55
Current hyperactive	9.54	5.97	7.45	2.21	1.09
Current total score	38.27	16.16	31.00	7.38	1.36
Childhood inattention	25.00	6.16	14.10	5.22	4.35*
Childhood hyperactive	20.09	8.19	14.10	6.06	1.89*
Childhood total score	45.09	13.17	27.10	8.23	3.70*
ASRS					
Total Symptom Count	5.00	1.00	3.81	1.68	2.37*
BDI-II					
Total Score	11.64	8.08	10.60	9.82	0.30
BAI					
Total Score	13.15	5.91	5.30	4.92	3.84*

Note: BAARS-IV = Barkley Adult ADHD Rating Scales – IV; ASRS = Adult ADHD Rating Scale; BDI – II = Beck Depression Inventory-II; BAI = Beck Anxiety Inventory.* = $p < .05$.

Table 4. Between-group differences in activity level, task performance, and visual attention to task

	ADHD		Comparison		Effect Size	
Activity Level	Mean	SD	Mean	SD	Cohen's d	*t*
Average control condition 1	6549.39	4333.84	4564.85	1678.31	.60	1.84
CPT	14210.37	11346.93	4215.55	3090.53	1.20	2.96*
Average control condition 2	8256.77	2791.80	8237.08	3529.58	.01	0.29
Task Performance						
Total Errors on CPT	20.03	19.54	8.54	7.54	.78	1.91
Visual attention to task						
Percent on-task control task	99.46	.84	99.69	.55	.32	0.90
Percent on-task CPT	100.00	0.00	100.00	0.00	.00	-

Note: CPT = Continuous Performance Test; Actigraph Proportional Integrating Measure (PIM) Values can range from 0 (no movement) to 65,535; * = $p < .05$

Table 5. Activity level during tasks analyses.

	Activity level[a]					
	C1	CPT	C2	Group Composite		
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SE)	*F*	Contrasts
ADHD Group	6549.39 (4333.84)	14210.37 (11346.93)	8256.77 (2791.80)	9672.17 (1159.90)	5.46*	C1<C2<CPT
Comparison Group	4564.85 (1678.31)	4215.55 (3090.53)	8237.08 (3529.58)	5672.49 (1073.86)	20.77*	CPT<C1<C2
Activity Level Composite	5557.12 (626.18)	9212.96 (1575.87)	8246.93 (631.90)	-	5.12*	C1<C2<CPT

Note: CPT = Continuous Performance Test; Actigraph Proportional Integrating Measure (PIM) Values can range from 0 (no movement) to 65,535; Standard errors are presented for group composite. C1 = control condition (pre); C2 = control condition (post); SE = standard error; * = $p < .05$

[a] Group x condition interaction, $F(1.35,32.37) = 9.97$, $p = .002$

Table 6. Correlation between task performance and activity level during the CPT

	1	2
1. Total Errors CPT	___	
2. TES CPT	.444*	___

Note: * = *p* =.026; CPT = Continuous Performance Test

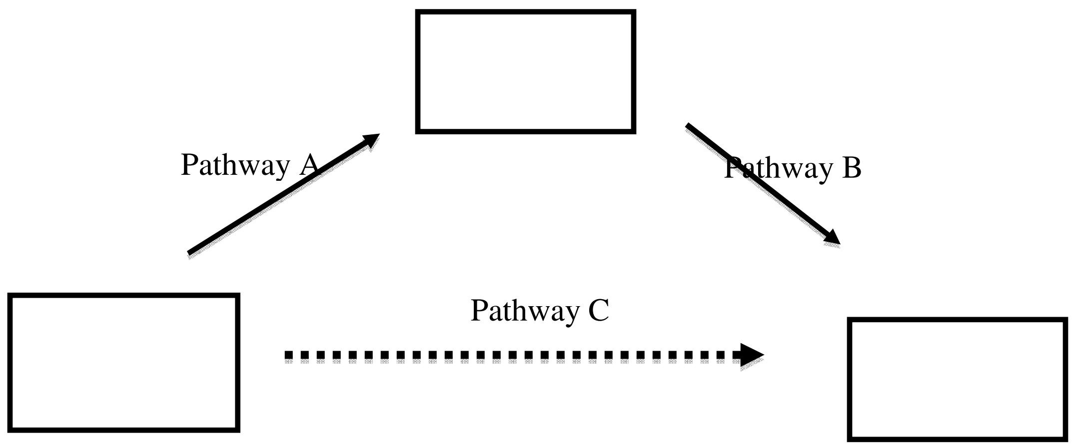

Figure 1. Proposed meditational model with total errors as cognitive performance outcome variables.

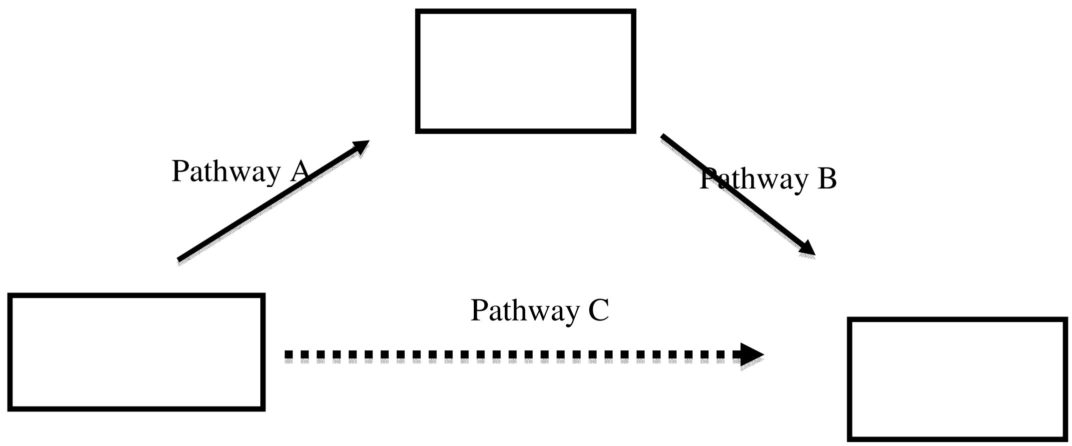

Figure 2. Proposed meditational model with omission errors as cognitive performance outcome variable.

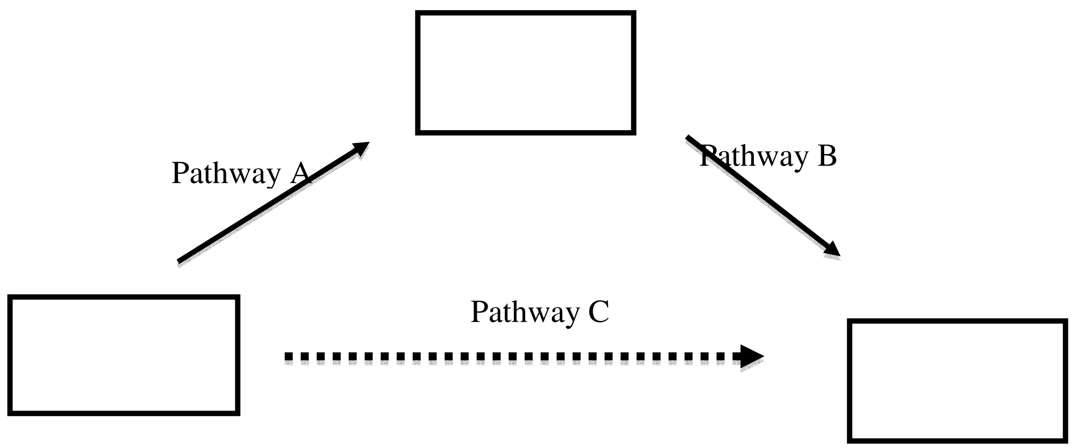

Figure 3. Proposed meditational model with commission errors as cognitive performance outcome variable.

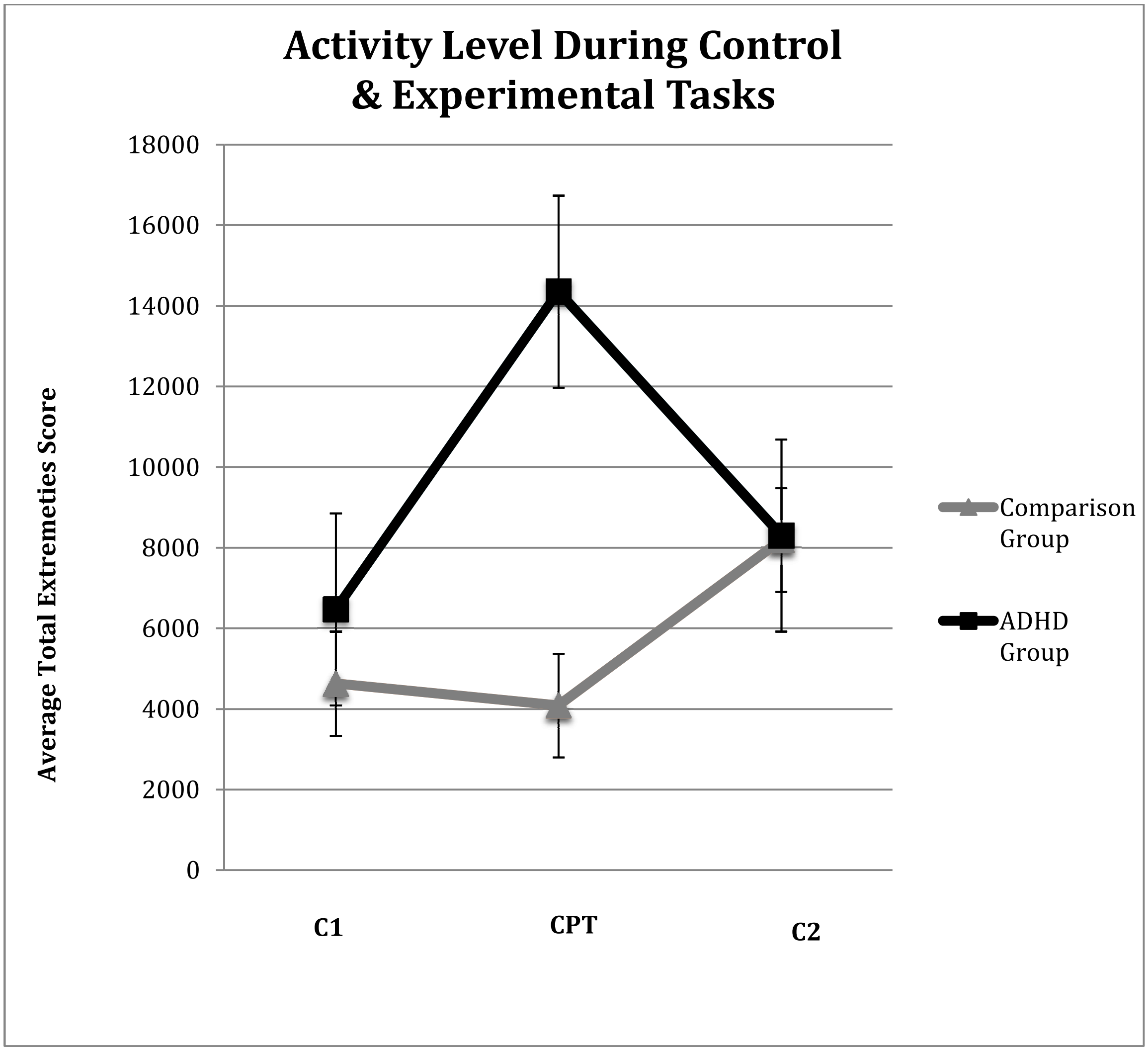

Figure 4. Plotted means of total extremities scores over the three experimental tasks. Actigraph Proportional Integrating Measure (PIM) Values can range from 0 (no movement) to 65,535.

Vita

Brianna Elizabeth Pollock was born and raised in Hunlock Creek, Pennsylvania. She earned her Bachelor of Science degree in Honors Psychology at the University of Pittsburgh. She began her doctoral training in Clinical Psychology at the University of Tennessee – Knoxville in 2012. Her research interest includes the cognitive, social and emotional development of children and adults with ADHD.