Impairment in adult ADHD: Effects of ADHD symptoms, executive function, and sleep

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While Attention-deficit/hyperactivity disorder (ADHD) remains one of the most common psychological disorders diagnosed, current understanding of the disorders expression and factors contributing to impairment in early adulthood remains limited. In an effort to better understand current issues with ADHD assessment and treatment in emerging adults, this study aimed to examine relationships between symptoms, executive function (EF), sleep, and impairment. Overall results of this study indicate that together, ADHD symptoms, EF, and sleep account for a significant proportion of variance in impairment. Additionally, results indicate that EF moderates the relationship between ADHD symptoms and impairment, and that sleep may be a protective factor for adults. Specifically, this study found that when compared to individuals reporting more sleep problems, the effect of ADHD symptoms and EF on impairment was much weaker among individuals reporting fewer sleep problems. Understanding the relationship between ADHD symptoms, EF, and sleep is critically important in better understanding adult ADHD and in informing assessment and treatment strategies to more effectively reduce impairment.

DEDICATION

This dissertation is dedicated to my loving wife and parents, without whom this would not have been possible. I am eternally grateful for their patience, kindness, and support. In addition, this dissertation is dedicated to my mentor, Dr. Kevin J. Armstrong. He has provided guidance and support that have contributed significantly to my development as a psychologist and as a person.

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CHAPTER I

INTRODUCTION

Attention-Deficit/Hyperactivity Disorder (ADHD) is one of the most common psychological disorders diagnosed during childhood and adolescence. Estimates indicate that between 2.5 % and 4% of adults in the U.S. meet criteria for ADHD (5th ed.; *DSM–5*; American Psychiatric Association, 2013; Kessler et al., 2006). However, only an estimated 10 – 25% of adults meeting diagnostic criteria are diagnosed and adequately treated (Castle, Aubert, Verbrugge, Khalid, & Epstein, 2007), indicating that ADHD remains vastly under recognized and undertreated in adults. This reflects the need to better understand the variables related to adult ADHD, and to develop improved measures and strategies for use in assessing adult ADHD.

The current body of literature identifies a number of variables that are important to consider when conceptualizing and assessing adult ADHD. Research on the relation between executive function (EF) and ADHD contributed to a shift away from viewing ADHD primarily as a behavioral disorder and provided evidence to support the classification of ADHD as a neurodevelopmental disorder. Although ADHD has increasingly come to be understood as resulting from executive dysfunction (Barkley, 2015), some studies have failed to demonstrate a difference in executive function (EF) between ADHD diagnosed adults and control samples (Saboya, Coutinho, Segenreich, Ayrão, & Mattos, 2009).

Current diagnostic criteria for ADHD put forth by the *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; *DSM–5*; American Psychiatric Association, 2013) partially reflect

the understanding of ADHD as a developmental disorder. In an attempt to improve utility and apply results from ongoing research suggesting the presentation and symptoms of ADHD differ for adults and non-adults, the *DSM*-5 deviates from previous iterations of the manual, allowing for a diagnosis of ADHD in adults and including diagnostic criteria for adults (age 17 and older) that are slightly reduced (American Psychiatric Association, 2013). Specifically, diagnostic criteria addressing inattention symptoms require ADHD individuals under age 17 have six or more of the nine symptoms vs. a minimum of five inattention symptoms for individuals age 17 or older. Likewise, hyperactive criteria require six or more symptoms for individuals under age 17 vs. a minimum of five symptoms for individuals 17 or older in order to meet the diagnostic threshold. However, symptoms and current diagnostic criteria alone are not adequate when assessing for ADHD in adults. Research reporting that a significant number of adults exhibit ADHD symptoms that result in clinically significant impairment and meet all diagnostic criteria except that *DSM*-5 criteria requiring evidence of childhood onset (Castellanos, 2015) illustrates the need for a better understanding of how ADHD symptoms develop and present in adults (American Psychiatric Association, 2013). A well-known challenge for clinical researchers in this field is that ADHD symptoms can be related to a number of factors (Barkley, 2015). Researchers have investigated a number of targets that seem to evoke or exacerbate ADHD symptoms such as poor delay of gratification, frustrated or unsatisfactory social relationships, and environmental stressors related to work and family (Barkley et al., 2006; Barkley & Fischer, 2011). Two important factors that affect symptom presentation and the degree of impairment experienced by individuals include sleep and executive function skills. This paper addresses how these two factors (i.e., sleep and executive functioning) influence the impairment associated with ADHD symptoms.

Impairment and sleep are both important in conceptualizing and understanding adult ADHD. Significant impairment is currently a diagnostic criterion for the diagnosis of ADHD (American Psychiatric Association, 2013), however, conceptualizing impairment as resulting directly from symptoms and their severity (how often they occur) is an oversimplified and inadequate explanation for why impairment occurs. Sleep problems can exacerbate impairment and ADHD symptoms, and research indicates that 60-80% of adults diagnosed with ADHD experience clinically significant symptoms of sleep disorders, however sleep problems are rarely addressed in ADHD screeners and the relation between sleep and ADHD is not adequately understood (Yoon, Jain, & Shapiro, 2012).

Literature provides a significant amount of information about the relations between EF, symptoms, impairment, sleep and ADHD, and contributes to current understanding of ADHD. The inadequacy of explanations regarding causal relations and interactions between EF, symptoms, impairment, and sleep as they relate to adult ADHD contributes to concerns over the validity of adult ADHD assessment and diagnosis. A more integrative understanding of how these variables interact with each other will contribute to a better understanding of adult ADHD, and improve assessment, diagnosis, and intervention strategies. Specifically, integration of information from literature addressing each variable and their interactions will contribute to the development of screening tools and assessment strategies with improved validity that result in fewer false positives and false negatives.

ADHD Symptoms and EF

Recognizing that executive function is important in nearly every life domain (Diamond, 2013), ADHD has come to be understood as a disorder of executive functioning and research on relations between ADHD symptoms and EF has begun to influence how adult ADHD is

conceptualized and assessed (Barkley, 2015; Willcutt, Doyle, Nigg, Faraone & Pennington, 2005; Silverstein et al., 2018). Research indicates that executive function is a reliable diagnostic indicator of adult ADHD (Kessler et al., 2010) and that executive function allows individuals to define, organize, and enact plans across time to achieve delayed goals that may even involve short-term cost to the individual (Barkley, 2015). Symptoms of adult ADHD (age 17 and older) as dictated by the *DSM-5* are slightly reduced compared to criteria for those under age 17, and the essential diagnostic feature remains a persistent pattern of inattention and or hyperactivity-impulsivity that interferes with functioning or development (5th ed.; *DSM–5*; American Psychiatric Association, 2013).

The executive function theory of ADHD is a prominent neuropsychological explanation of ADHD symptoms. It suggests that deficits in executive function (defined as "neurocognitive processes that maintain and appropriate problem-solving set to attain a later goal") give rise to ADHD symptoms (Willcutt et al., 2015). Indeed, research investigating differences in executive function among adult ADHD individuals and others reported significantly greater executive functioning deficits in adults with ADHD when compared to a control (Biederman et al., 2006). However, other literature focusing on the relations between adult ADHD symptoms and executive function cautions that although a clear link among symptoms and deficits in executive function are well documented in current literature and may be drawn during comprehensive assessment, the constructs are not identical and are only partially correlated (Barkley, 2015).

A comprehensive meta-analysis evaluating the validity of the executive function theory of ADHD reported that ADHD is consistently associated with significant executive function deficits in several domains including response inhibition, vigilance, working memory, and planning (Willcutt et al., 2015). However, researchers go on to explain that executive function

deficits are not universal among ADHD individuals and that although executive function is an important factor influencing ADHD symptoms, symptom expression, and impairment, executive function deficits alone do not cause ADHD nor do they provide adequate explanation for the disorder (Willcutt et al., 2015). Further establishing executive function and ADHD symptoms as separate constructs, research has reported a range of executive functions among individuals endorsing either high or low numbers of ADHD symptoms (Dorr & Armstrong, 2018).

Research on the core structure of executive function has not reached consensus. Generally, however, executive function is considered a multidimensional construct with three core components including inhibition or inhibitory control, working memory, and cognitive flexibility or metal shifting (Miyake et al., 2000; Diamond, 2013). Executive functions have important implications for how ADHD is expressed and impairment, however measures of executive function differ in the type of information they provide. Research on the validity of executive function assessments used in young adults explains that laboratory-based and task performance tests, ecologically based tests, and self-rating scales are the three primary strategies used to measure executive function (Duggan, Garcia-Barrera, & Müller, 2016). Laboratory and task-based strategies are effective for measuring executive function ability and are useful in research focusing on executive function structure, however they do not reflect actual behavior (Duggan et al., 2016). Additionally, laboratory and task-based measures may indicate executive function impairment in individuals who are not experiencing daily impairment in life domains (Kessler et al., 1996). Ecologically-based measures in which individuals interact with specific situational contexts provide information useful for treatment planning for clinical populations and older adults but are not sensitive measures of executive function (Duggan et al., 2016). Self-report measures of executive function provide information about daily executive function

through behavioral expressions (Duggan et al., 2016). Additional research reported that performance-based measures of executive function correlate only slightly with rating measures $r = .19$, and concluded that they measure different constructs (Toplak, West, & Stanovich, 2013). Results reported by Toplak et al. (2013) suggest that performance-based measures reflect cognitive efficiency, whereas rating measures reflect goal pursuit (which may be interpreted as the extent to which individuals engage executive function processes).

As explained by Diamond (2013) executive functions are influenced by a number of social, emotional, and physical factors that can result in impaired executive function including "stress, lack of sleep, loneliness, or lack of exercise." Because self-report measures of executive function provide information about actual behaviors in these domains they are more useful than other measures for research examining interactions between executive function and other constructs. Additionally, because executive functions are trainable and can be improved (Diamond, 2013) self-report measures may provide unique information to researchers identifying how executive function interacts with ADHD symptoms and sleep, which may then inform intervention strategies and improve their ability to reduce impairment.

ADHD Symptoms, Executive Function, and Impairment

Conceptually, ADHD symptoms are the behavioral and cognitive expressions that result in impairment. Specifically, symptoms are the actions believed to reflect ADHD including inattention, distractibility, impulsive responding, and hyperactivity (Barkley et al., 2006). Impairment is conceptualized as the resulting consequences of symptoms that cause distress in domains including family, work, academic, social, risk taking, life skills, and emotions among others (Barkley et al., 2006). Overlooking details or regularly failing to give close attention, difficulty sustaining attention, quickly losing focus on tasks, mind wandering, organizational

difficulties, procrastination of tasks requiring sustained mental effort, losing things, and being easily distracted or forgetful are symptoms included as inattentive diagnostic criteria for ADHD in the *DSM*-5 that may result in impaired functioning in one or more life domain (American Psychiatric Association, 2013).

In the *DSM*-5, diagnostic criteria for behaviorally expressed symptoms of hyperactivity and impulsivity that may result in impairment including fidgeting, tapping, and squirming, frequently leaving when expected to remain seated in a classroom, at work, or elsewhere, excessive physical motor behavior in inappropriate situations or feeling restless, difficulty participating in leisure activities, being uncomfortable when sitting still or being unable to do so, excessive talking, interrupting others, underdeveloped sense of patience, and intruding on conversations, activities, games, and assignments or work tasks (American Psychiatric Association, 2013).Regarding ADHD impairment, the *DSM*-5 criteria require evidence that symptoms interfere with or impair functioning in multiple domains, and specify the ADHD diagnosis as mild, moderate, or severe (American Psychiatric Association, 2013). In the *DSM*-5 severity is determined based on number of symptoms present, the number of domains in which individuals are impaired, how often symptoms occur, and how the significance of impairments relates to the symptoms.

Severity as it is used in the *DSM*-5 reflects how symptom severity has been conceptualized and used in ADHD literature, screening strategies, and assessment tools. For example screening instruments such as the Adult ADHD Self-Report Scale version 1.1 (ASRS v1.1) which was developed by the World Health Organization (WHO) as a means for providing a valid self-assessment of ADHD symptoms, determine severity by number of symptoms endorsed (Kessler et al., 2005). Similar to the *DSM*-5, higher symptom count suggests greater severity in

the ASRS v1.1 (Kessler et al., 2005), which is related to more severe functional impairment or impairment in more life domains.

Executive function is generally considered to include cognitive processes that facilitate problem solving and goal achievement. Summarizing current literature, Barkley (2015) explains that intact executive function provides individuals with the ability to achieve goals. Specifically, EF facilitates goal achievement as it provides individuals with the ability to define, organize, and enact plans across time singularly or by utilizing advantages and resources related to interacting with others and through the use of social supports, when reward or goal achievement is delayed and when achievement requires short-term costs (Barkley et al, 2015; Willcutt, 2015). Among competing theories of ADHD, it is hypothesized that ADHD symptoms and impairment arise from weaknesses in EF affecting inhibition and working memory, delay aversion, reward and punishment response, and cognitive processing speed (Luman, Oostetlaan, & Sergeant, 2005; McGrath et al., 2011; Pennington & Ozonoff, 1996; Shanahan et al., 2006; Sonuga-Barke, Taylor, Sembi, & Smith, 1992). Deficits in EF are associated with a number of impairments across life domains. Additionally, variables such as sleep that affect EF or an individual's ability to engage EF skills contribute to and may worsen EF related impairment.

In a review of literature focusing on executive function, Diamond (2013) identifies 8 specific domains in which executive functions are crucial to adequate individual function including mental health (Baler & Volkow, 2006; Barch, 2005; Fairchild et al., 2009; Lui & Tannock, 2007; Penades et al. 2007; Tavares et al., 2007), physical health (Crescioni et al., 2011; Miller, Barnes, & Beaver, 2011; Riggs, Spruijt-Metz, Sakuma, Chou, & Pentz, 2010), quality of life (Brown & Landgraf, 2010), school readiness (Blair & Razza, 2007), school success (Borella, Carretti, & Pelegrina, 2010; Duncan et al., 2007; Gathercole, Pickering, Knight, & Stegmann,

2004), job success (Barkley & Fischer, 2011; Bailey, 2007), marital harmony (Eakin et al., 2004), and public safety (Broidy et al., 2003; Denson, Pedersen, Friese, Hahm, & Roberts, 2011). Executive function deficits are associated physical health impairments including obesity, poor eating habits, and substance abuse (Crescioni et al., 2011; Miller, Barnes, & Beaver, 2011; Riggs et al., 2010). Research on quality of life reports that individuals with lower executive function report a greater number of problems, less satisfaction, and a lower quality of life overall (Brown & Landgraf, 2010). Executive function deficits affect school readiness and are associated with impaired self-control and poorer self-regulation skills that contribute to difficulties transitioning into the classroom (Blair & Razza, 2007, Diamond, 2013). Executive function deficits in ability to sustain attention reduce school success and are associated with poorer math and reading competence (Borella, Carretti, & Pelegrina, 2010; Duncan et al., 2007; Gathercole, Pickering, Knight, & Stegmann, 2004). Job success is affected when impaired productivity contributes to difficulty finding, keeping, and advancing in employment opportunities (Barkley & Fischer, 2011; Bailey, 2007). Executive function deficits are also associated with difficulty regulating mood, and romantic partners with executive function deficits may be more impulsive, less dependable, and may argue more (Eakin et al., 2004; Penades et al., 2007; Tavares et al., 2007; Fairchild et al., 2009; Baler & Volkow, 2006). Finally, public safety is affected as individuals with executive function deficits experience more social problems resulting from emotional, criminal, violent, or reckless behaviors (Broidy et al., 2003; Denson, Pedersen, Friese, Hahm, & Roberts, 2011).

Research has reported that self-ratings of executive function predict impairments in occupational functioning and impairment in other major life activities, and that self-ratings that reflect behavior are superior to task performance-based measures in their predictive value

(Barkley & Fischer, 2011). Using self-report measures, additional research on executive function in young adults reported that lower executive function is predictive of impaired planning and academic performance (Baars, Bijvank, Tonnaer, Jolles, 2015). Considering the strong negative correlations between executive function and both symptoms and impairment, in addition to research suggesting that higher executive function may protect against impairment by enabling individuals to engage in coping strategies that lower executive function peers lack (Dorr & Armstrong, 2018), an understanding how these variables interact is necessary for current conceptualizations of adult ADHD to evolve. In addition to these relations, sleep is another variable with important implications for executive function, ADHD symptoms and impairment. As a result, improving impairment prediction necessitates the inclusion of sleep, ADHD symptoms, and executive function

Sleep and ADHD symptoms

Researchers have found a strong relation between sleep quality and adult ADHD presentation (Bogdan & Reeves, 2018), noting that increased likelihood of reporting ADHD symptoms is associated with both elevated and diminished sleep duration. The National Institutes of Health (NIH) estimate that as many as 70 million Americans are affected in some life domain by sleep-related problems. Sufficient sleep, defined as the amount of sleep required for optimal mental and physical function differs depending on age, however, insufficient sleep is associated with increased risk of psychiatric and physical disorders (NIH, 2018). Among adults with ADHD, the greater symptom severity resulting from elevated or diminished sleep duration may contribute to greater impairment in functioning across life domains (Bogdan & Reeves).

Literature reports that sleep has a number of significant implications for ADHD symptoms in adults. A large population-based study of 16 to 19 year olds reported that shorter

sleep duration, longer sleep latency, nocturnal wake time, larger sleep deficiencies, insomnia and delayed sleep phase syndrome were associated with ADHD symptoms (Hysing, Lundervold, Posserud, & Sivertsen, 2016). In their study, significantly more individuals high in ADHD symptoms (as measured by the ASRS) slept less than 4 hours per night (19%) when compared to individuals with low ASRS scores (7%). This study also reported a significant difference in sleep deficiency (defined in their study as the difference between sleep duration and subjective sleep need) between individuals with high ASRS scores and low ASRS scores. Among these groups a sleep deficiency of more than 5 hours was documented in 31% of high ASRS individuals compared to only 10% of individuals with low scores . These findings expanded upon previous research reporting that both inattentive type and hyperactive/impulsive type ADHD individuals are more likely to report current and lifetime sleep problems (Gau et al., 2007). Interestingly, inattentive type ADHD individuals were more likely to report a greater difference between sleep need and sleep duration than hyperactive type individuals, and that hyperactivity was associated with less sleep overall.

Sleep problems were included as diagnostic criteria for ADHD in previous editions of the *DSM,* but were removed because of their poor specificity (Cortese, 2015). Initially, inclusion of sleep problems reflected a clinical awareness of sleep problems being a common problem among ADHD diagnosed adolescents. However, reviews and meta/analyses (Cortese et al., 2005; Cortese, Farone, Konofal, & Lecendreux, 2009; Konofal, Lecendreux, & Cortese, 2010; Sadeh, Pergamin, & Bar-Haim, 2006; Sedky, Bennett, & Carvalho, 2014) of research on sleep and ADHD symptoms provide strong evidence that ADHD is significantly associated with both subjective and objective sleep and alertness alterations (Cortese, 2015).

In ADHD adults, the literature also suggests that poor sleep in general is associated with ADHD symptoms and symptom severity (Bijlenga et al., 2013; Bjorvatn, 2017). Together, findings from reviews, meta analyses, and the literature concerning adult ADHD symptoms and sleep highlight the significance of sleep in conceptualizing ADHD and the importance of assessing for sleep in ADHD screenings and during assessments.

Sleep and Impairment

In general, sleep quality is associated with a host of health and life quality factors that are both physical and psychological in nature. Researchers have found that sleep is linked to obesity (Kohatsu et al., 2006), diabetes maintenance, development of type 2 diabetes and insulin regulation (Gottlieb et al., 2005; Knutson, Ryden, Mander, & Van Cauter, 2006; Nilsson, Rööst, Engström, Hedblad, & Berglund, 2004), stroke, cardiovascular disease, hypertension, and coronary heart diseases (Itani, Jike, Watanabe, & Kaneita, 2017), immune function (Irwin, & Opp, 2017), and hormone regulation involved cardiovascular function, stress response and appetite (Spiegel, Tasali, Penev, & Van Cauter, 2004; Irwin, Olmstead, & Carroll, 2016; Sleep and Health, 2008). The significant impact sleep has on health and well-being is especially highlighted by research reporting a strong association between sleep duration and mortality. According to longitudinal studies it appears that either too little or too much sleep places adults at an increased risk for mortality (Hublin, Partinen, Koskenvuo, & Kaprio, 2007), and research on sleep and mortality consistently demonstrates that across age ranges mortality risk increases as nightly sleep deviates from 7 to 8 hours nightly (Grandner, Hale, Moore, & Patel, 2010). Clearly, current literature illustrates the significant physical impairments associated with sleep. Additional sleep research illustrates the significant ramifications sleep has on cognitive and psychological functioning.

Sleep has significant implications for cognitive functioning including learning and memory (Karni, Tanne, Rubenstein, Askenasy, & Sagi 1994), and both behavior and emotion regulation (Vandekerckhove, & Cluydts, 2010). Sleep is associated with impairment, defined here as behaviors or emotions resulting in distress in domains including family, work, school, life skills, self-concept, social, and risk taking among others (Vandekerckhove & Cluvdts; Bogdan & Reeves).. Specifically, sleep may contribute to impairment or may serve as a protective factor against it. Research indicates that poor sleep quality has a significant impact on cognition. Literature addressing sleep and cognition consistently reports that good sleep quality both promotes better cognitive functioning and protects against cognitive declines in young adulthood through middle age (Scullin, & Bliwise, 2015). Likewise, it has been consistently reported that poor sleep quality, specifically sleep deficit, impairs memory, attention, and executive function (Bonnet, 2005). If lack of sleep has cognitive effects as documented in the literature, then it is reasonable to assume that poor sleep quality may exacerbate psychopathological presentations and impairment. As it relates to the proposed study, this has important implications for adult ADHD conceptualization, assessment, and screening.

Investigating the interaction between sleep and psychological functioning, research reports that sleep affects how individuals cope with and react to daily activities and stressors, and that the events occurring over the course of the day in turn affect sleep. The literature suggests that generally, poor sleep or sleep deprivation may result in individuals being more sensitive to emotional and stressful events, and impair ability to cope with and perform daily activities or roles (Vandekerckhove, & Cluydts, 2010). Other research investigating the interplay between sleep and mood, academic functioning, physical health, and psychological health reported that in emerging adults (individuals age 18 to 25) sleep duration and quality may serve as a risk or

protective factor against impairment (Wong et al., 2013). Specifically, results reported that sleep quality predicted psychological factors including depression, anxiety, and self-esteem, in addition to predicting academic functioning and physical health (Wong et al., 2013). Research investigating the relation between depression and sleep reports that for adults, sleep outside of the optimal age appropriate amount, including both shorter and longer sleep duration, is significantly predictive of depression (Zhai, Zhang, & Zhang, 2015). Research investigating the relations between anxiety, sleep, and functional impairment report that anxiety disorders and lower reported quality of life is associated with poor sleep (Ramsawh, Stein, Belik, Jacobi, & Sareen, 2009). Taken together, sleep has both direct and indirect influence on mental health, as it can directly affect mood (Wong et al., 2013) and indirectly as poor sleep can affect or ability to cope with and process daily events and responsibilities (Vandekerckhove, & Cluydts). Additionally, sleep may serve as either a risk factor or protective factor against psychological disorders, as poor sleep quality may worsen clinical psychological symptoms. Clearly then, it is important to understand and consider sleep during psychological assessments, as sleep may present as an important treatment target in efforts to reduce individual impairment. Likewise, it is equally important to consider sleep in order to avoid mistakenly attributing presentation of symptoms included in diagnostic criteria to a disorder, rather than resulting from sleep hygiene.

Sleep and Executive Function

Literature addressing the relation between executive function and sleep reports a number of findings with important implications for the current study. In general, reviews of current literature addressing sleep and cognition such as that conducted by Walker (2009) report a consensus that sleep has a clear and significant link with cognitive processes. Other research on the relation between sleep and executive function indicates that sleep deprivation and poor sleep

quality significantly affect executive function and cognition in young adults (Goel, Rao, Durmer, & Dinges, 2009; Wilckens, Woo, Kirk, Erickson, & Wheeler, 2014).

Executive functions performance may fluctuate as it is influenced by a number of variables including sleep (Friedman et al., 2016; Kuula et al., 2018). Research focusing on the interaction between sleep and executive function reports that both sleep deprivation or insufficient sleep and circadian misalignment are predictive of poorer executive function (Jackson et al., 2013; Kuula et al.; Lo et al., 2012). Kuula et al. found significant relations between sleep and both self-reported and performance-based executive function measures. Their results suggest that among young adults, who when compared with other age groups experience more irregular sleep in addition to environmental changes, such as moving for school or work, and biological changes that also affect sleep, executive function is impaired by short sleep (Kuula et al.). Additionally, irregular sleep was associated with poorer performance on some executive function tasks of motor function, and later circadian rhythm was associated with longer sleep duration and poorer executive function self-ratings but not performance based executive function ratings (Kuula et al.). Additional research on more specific domains of executive function, such as that conducted by Wilckens et al. (2014) reported that sleep is particularly important for executive functions among young adults. Wilckens et al. measured working memory using a computerized version of the Sternberg working-memory task (Sternberg, 1966), inhibition using computerized version of the Stroop and Flanker tasks, processing speed using the Trails A (Reitan, 1958) and the digit-symbol substitution subtest of the Wechsler Adult Intelligence Scale III (Wechsler, 1997), and recall using the Consortium to Establish a Registry for Alzheimer's disease (CERAD) Word List Memory test (Moms et al., 1989). Results found that sleep continuity, and total sleep time (specifically very short and very long total sleep time)

significantly affect executive functions. Specifically, better sleep was associated with working memory and inhibition among young adults (Wilckens et al.).

Sleep, Executive Function, ADHD Symptoms, and Impairment

Considering the significant interactions between sleep, ADHD symptoms, executive function, and impairment and how each is considered in current conceptualizations of ADHD in adulthood, it is critically important to understand how symptoms, sleep, and executive function interact to predict impairment. Previous research has reported that executive function may serve as a protective factor against ADHD symptom related impairment (Dorr & Armstrong, 2018). If chronic poor sleep, aside from contributing to impairment directly, impairs executive function, which independently is associated with ADHD symptoms and impairment, and reduce the effectiveness or availability of executive functions, then individuals may experience more symptoms, more frequently. This interaction may facilitate greater impairment than ADHD symptoms, sleep problems, and executive function deficits individually. Because sleep interacts with executive function it is reasonable to postulate that because sleep also interacts with both symptoms and impairment, poor sleep may be contributing to impairment directly, and facilitating greater impairment indirectly due to executive function decline associated with poor sleep. Currently, no known studies have reported on how interactions among executive function, sleep, and ADHD symptoms combine to influence impairment. Research has thoroughly established the importance of each variable of interest to this study (i.e., executive function, ADHD symptoms, and sleep) as distinct constructs that are predictive of impairment. This study tested a model for how these variables interact to predict impairment. The model has implications for how ADHD is both assessed and treated in emerging adult populations.

Hypotheses

Preliminary analyses of responses to measures used in this study were expected to show a) a positive correlation between ADHD symptom severity and overall impairment, b) a negative correlation between ADHD symptom severity and executive function, c) a positive correlation between ADHD symptom severity and sleep, d) a negative correlation between overall executive functioning and overall impairment, e) a negative correlation between executive function and sleep, and f) a positive correlation between overall impairment and sleep.

The primary hypotheses of this project were more specific: Please refer to Figure 1 (PROCESS Model 59: Hayes, 2013).

1) There will be an indirect effect of ADHD symptoms on impairment through executive function that will be moderated by sleep.
    a. Specifically, sleep will moderate the relation between executive function and impairment.
    b. Executive function will moderate the relation between ADHD symptoms and impairment.

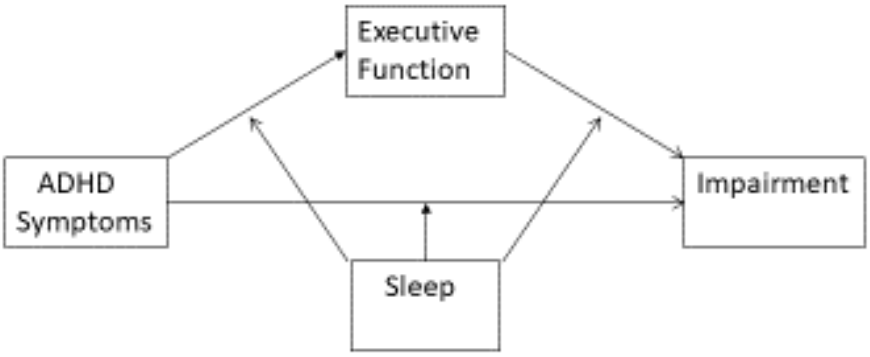

Figure 1. *PROCESS Model 59: Hayes, 2013*

CHAPTER II

METHOD

Participants

Data collection occurred during the spring semester of 2019. The initial sample consisted of 250 participants recruited from MTurk. Two indicated that their data should not be used and were discarded. Five responses were discarded because total time taken to complete the task was less than 5 minutes. Thirteen records were discarded because they failed one or both validity scales included in the task. Finally, fifteen were discarded because they responded either AM or PM when asked to indicate when they usually went to bed or when responding to an item asking them to indicate when they usually wake up. These responses were excluded because a more specific response indicating approximate sleep and wake times is needed for responses to be included in this project's primary analysis. The final sample consisted of 215 participants.

Materials

The link for the survey on Qualtrics was accessed by MTurk workers via TurkPrime.com and completed online. Participants were paid $3.00 for completing the survey. The Externalizing Disorders lab and the Mississippi State University Psychology department provided funding for this project. Each participant received the same questionnaire, answering up to 315 items. Demographic questions asked about the following: ADHD diagnosis, age, gender, ethnicity, highest level of schooling, and asked participants to indicate if English is their first language.

Measures

Validity Scales

The Elemental Psychopathy Assessment (EPA; Lynam et al., 2011), the infrequency scale, and the virtue scale were validity scales included in the questionnaire. A score of 4 or greater on the infrequency scale (which consists of 8 items individuals may endorse when not paying attention) or a score of 3 or greater on the virtue scale (which consists of 8 items assessing behaviors or virtues) suggest invalid responses (Lynam et al., 2011; Miller et al., 2011).

ADHD Symptoms

The Adult ADHD Self-Report Scale 1.1 (ASRS v1.1) includes 18 items reflecting diagnostic criteria for ADHD in the DSM-IV. In an effort to provide a valid self-assessment of ADHD symptoms, the scale was developed by the World Health Organization (WHO) (Kessler et al., 2005; Ustun, 2005). The ASRS v1.1 uses adult-specific language and symptoms are rated on a 0-4 scale. A positive score is interpreted as evidence that the individual is at elevated risk for ADHD and should seek a clinical evaluation.

The Adult ADHD Self-Report Scale-Expanded Version includes nine items assessing for executive function deficits (EFDs), and four items assessing emotional dyscontrol (ECs) in addition to 18 items assessing core DSM-5 adult ADHD symptoms (Silverstein et al., 2018). The previous iteration, the Adult ADHD Self-Report Scale version 1.1 (ASRS v1.1) assesses symptoms using a symptom count. Neither the ASRS v1.1 or the expanded edition provide a diagnosis, rather results are interpreted as risk level for adult ADHD.

The Adult ADHD Self-Report Scale (ASRS)-Expanded Version was developed by the World Health Organization (WHO) adult ADHD work group in an effort to produce an updated

scale that reflects the expanded ADHD criteria of the DSM-5 (Silverstein et al., 2018; Utsun et al., 2017). Research on the validity of the Adult ADHD Self-Report Scale-Expanded Version reports that the 31-item screener has high validity assessing 18 core ADHD symptoms (responses on these core 18 items have a range of 0 - 72), executive function deficits, and emotional control symptoms (Silverstein et al., 2018; Utsun et al., 2017). Additionally, it was demonstrated to have good sensitivity and specificity (Silverstein et al., 2018; Utsun et al., 2017). Like the ASRS v1.1, the expanded version is adult specific and uses adult specific language. Responses reflect how respondents have felt and conducted themselves in the past month and are recorded using a Likert scale ranging from 0 - 4. Specifically, 0 indicates "never," 1 "rarely," 2 "sometimes," 3 "often," and 4 indicates "very often." Higher scores indicate increased symptomology. Although alternative measures exist, advantages of the ASRS-Expanded Version include good reliability and validity, and the ability to easily adapt items to a format that may be administered online (Silverstein et al., 2018). Additionally, the measure is short, helping reduce the overall time participants spend answering and helping protect against fatigue threatening validity. Inclusion of executive function items in the ASRS-Expanded Version will also provide future studies using this data with an opportunity to examine construct validity of the Executive Function Index (Spinella, 2005). Finally, the ASRS-Expanded Version provides a range for responses between 0 and 124 and is appropriate for use in this study

Impairment

Common impairment assessment measures used in research and in clinical settings include quality of life scales such as the Adult ADHD Quality-of-Life Scale (AAQOL; Brod, Johnston, Able, & Swindle, 2006), and functional impairment scales including the Weiss

Functional Impairment Rating Scale – Self Report (WFIRS-S; Weiss, 2000). For the purpose of this study, an impairment measures that is specific to adults and ADHD was selected.

The WFIRS-S is a 69-item ADHD specific measure developed for use with adults that assesses impairment in a number of domains important to researchers and clinicians including family relations (8 items), work adjustment (11 items), school performance (11 items), life skills (12 items), self-concept (5 items), social functioning (9 items), and risk taking (14 items) (Canu, Hartung, Stevens, & Lefler, 2016). The WFIRS-S instructs individuals to "circle the rating that best describes how your emotional or behavioral problems have affected each item in the last month," (Weiss, 2000). Responses on a Likert scale indicate the frequency of impairment and range from "not at all," to "very often or very much."

The WFIRS-S provides both domain scores and a total score. Mean impairment rating (range 0-3) is calculated by summing all item response values and dividing by total number of items endorsed (Weiss, 2000). Items scored 2 "often or much," or 3 "very often or very much," are two standard deviations outside clinical norms and are considered impaired (Weiss, 2000). A minimum of two items scored 2 "often or much," or one item scored 3 "very often or very much," indicate impairment in a domain (Weiss, 2000). The theoretical range in response scores is 0 to 207. Higher scores indicate greater impairment.

Research on the psychometric properties of the WFIRS-S report excellent internal consistency, intercorrelations between domains, test-retest validity, sensitivity to change, internal consistency of greater than 9 and higher correlation between impairment change and symptom improvement than any previous measure (Weiss, 2000; Epstein & Weiss 2012). Additional research reports that the WFIRS-S has robust internal and concurrent validity, and cross-informant agreement equal or superior to other measures (Canu, Hartung, Stevens, & Lefler,

2016). Considering its psychometric properties, use in research, and the utility of the items included, the WFIRS-S is appropriate for this study.

Executive Function

Self-report measures of executive function are more appropriate for this study, as research indicates they are more predictive of individual behaviors and impairment (Baars, Bijvank, Tonnaer, Jolles, 2015; Barkley & Fischer, 2011). The Executive Function Index (EFI) is a self-report measure developed in a normal population and includes subscales derived through factor analysis of previous self-rating executive function measures (Spinella, 2005). Subscales include Motivational Drive (4 items), Organization (5 items), Strategic Planning (7 items), Impulse Control (5 items), and Empathy (6 items) (Spinella, 2005). Spinella (2005) reports that Empathy items reflect concern for others, prosocial behaviors, and cooperative attitudes, Strategic Planning items reflect tendencies to think ahead, plan, and use goal oriented strategies, Organization items reflect organized goal-directed behaviors and use of cognitive strategies including multitasking, sequencing, and holding information in mind to inform decisions, Motivational Drive items reflect behavioral drive, activity level, and interest in novelty, and Impulse Control items assess self-inhibition, risk taking, and social conduct (Spinella, 2005). Subscale score and a total score can be calculated using the 27 items, which are rated on a 5-point Likert scale (1 = Not at all, 3 = Somewhat, 5 = Very much). Individuals are asked to rate how well each item describes them. Higher scores indicate higher executive functioning.

Though other executive function measures exist, the EFI is appropriate for the current study for several reasons. Because the EFI was developed in a community sample using a factor analysis of other self-rating executive function measures, it incorporates a wide array of executive functions, all of which are not included in other self-rating or factor specific tasks and

screeners, and provides a more global measure of individuals executive functioning. Additionally it is easily adapted for administration online, can be easily administered to large samples, has strong correlations with other behavioral measures of executive function demonstrating convergent validity, and it has good intrascale reliability (Spinella, 2005), Responses to the EFI also provide a useful score range (0 to 108) for statistical analyses.

Sleep

A number of sleep measures exist that address a range of general and specific sleep issues. Considering the importance of relations between sleep and other variables of interest in this study measures that record data sufficient to support our analyses were considered. The Pittsburgh Sleep Quality Index (PSQI) (Buysse, Reynolds III, Monk, Berman, & Kupfer, 1989) is attractive and appropriate for the current study for a number of reasons. Consisting of 19 items, responses on the PSQI yield both a global score, and 7 component scores. Responses to the PSQI indicate individual experiences and behaviors for a majority of days and nights in the past month. Items 1-4 require individual responses regarding when individuals go to sleep, fall asleep, get up, length of sleep. Items 5 (which includes 10 sub items) through 8 are measured using a Likert scale. For these items 0 indicates "not during the past month," 1 "less than once a week," 2 "once or twice a week," and 3 indicates "three or more times a week." The Likert scale used for item 9 ranges from 0 "very good," to 3 "very bad."

The global score provided by the PSQI is used to distinguish between good sleepers "PSQI score > 5" and poor sleepers "PSQI < 5." Pittsburgh Sleep Quality Index global scores range from 0 (indicating better sleep) to 21 (indicating poorer sleep). This global score is calculated by summing component scores. Components of the PSQI include subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of

sleeping medication, and daytime dysfunction. For each component scores have a range of 0 (better) to 3 (worse).

In both clinical and community samples, the PSQI has been demonstrated to be a reliable and valid instrument, exhibiting good internal validity, test-retest reliability, and has been shown to be both diagnostically sensitive and specific (Backhaus, Junghanns, Broocks, Riemann, & Hohagen, 2002; Buysse et al., 1989; Carpenter & Andrykowski, 1998). Additionally, the PSQI can be easily adapted for online administration. For the current study, the global score provided by the PSQI will provide the greatest variance and will be appropriate for statistical analyses. Component scores may be useful in explanatory analyses examining more specific relations between these indices and executive function, impairment, and ADHD symptoms.

Copies of the measures are included in Appendix A.

Procedure

Participants were recruited via TurkPrime. TurkPrime recruits workers from Amazon Mechanical Turk (MTurk) who complete human intelligence tasks (HIT's) for financial compensation or other rewards. To improve generalizability to young adult populations, participants were restricted to individuals between age 18 and 25 who had an 80% approval rating (i.e., successfully completed 80% of studies) or better based on previous participation in MTurk tasks. This age range was selected to ensure maximum generalizability to other traditional emerging adult populations. Participants spent an average of 29.4 minutes (*SD* = 13.74) to complete the survey and were paid immediately

Design

General relations and hypotheses addressing the interactions between ADHD symptoms, executive function, sleep, and impairment were analyzed using correlational analyses, and regression-based analyses including PROCESS Model 59 (Hayes, 2013; moderated mediation). A bootstrapping method using 5000 resamples of the data was used to test for the significance of effects and produced 95% corrected confidence intervals (Hayes, 2013). Confidence intervals that do not contain zero indicate effects that are statistically significant. Because the analysis set bootstrapped samples to 5000 and considering our sample size of N = 215, analyses were adequately powered. In our primary analysis ADHD symptoms, executive function, sleep, and impairment were considered continuous variables. Total score on the Adult ADHD Self-Report Scale (ASRS)-Expanded Version (Utsun et al., 2017) was used to indicate symptom severity. Total score on the Executive Function Index (Spinella, 2005) was used to indicate level of recent and current executive function. Total score on the Pittsburgh Sleep Quality Index (PSQI) (Buysse, Reynolds III, Monk, Berman, & Kupfer, 1989) was used to indicate overall sleep quality. Total score on the Weiss Functional Impairment Rating Scale – Self Report (Weiss, 2000) was used to indicate impairment severity. In the analysis using PROCESS Model 59 (Hayes, 2013), it is hypothesized that sleep will moderate the indirect effect of ADHD symptoms on impairment via executive function and will moderate the relation between executive function and impairment.

This study was approved by the university's Human Subject Institutional Review Board (Appendix B).

CHAPTER III

RESULTS

In addition to reviewing the characteristics of the sample used in this research, this section discusses the general relations found between the 4 target variables (ADHD symptoms, executive functioning, sleep, impairment), and describes the analysis conducted for the hypothesis proposed. The analysis conducted for the primary Hypothesis assessed if executive function mediates the relation between ADHD symptoms and impairment, and if sleep affects the strength of relations between symptoms, executive function, and impairment. Statistical analyses were conducted using IBM SPSS Version 25.0 (IBM, 2017).

Demographics and Descriptive Statistics

The final sample consisted of 215 participants. Of this sample, 97 (45.1%) identified as male, and 118 (54.9%) identified as female. The majority of this sample (63.3%) identified as Caucasian (*n* = 136). In the remainder of the sample 24 (11.2%) identified as African American, 24 (11.2%) as Asian, 23 (10.7%) as Hispanic, 7 (3.3%) as other, and 1 (0.5%) identified as Pacific Islander. The median age was 23, however age mode was 24 (28.4%). The majority of the sample (*n* = 212; 98.6%) reported English as their first language. Most of the sample (*n* = 66; 30.7%) reported a bachelor's degree as their highest level of schooling. Of the remaining participants, 61 (28.4%) reported 1 or more years of college with no degree, 30 (14.0%) reported

receiving an associate's degree, 26 (12.1%) reported some college credit but less than 1 year, 25 (11.6%) reported receiving a high school diploma or GED, 4 (1.9%) reported 12th grade or less and no diploma, and 2 (0.9%) reported receiving a master's degree. One participant did not respond. Additionally, 32 (14.9%) reported a diagnosis of ADHD in their lifetime, and 183 (85.1%) reported never receiving a diagnosis of ADHD. Adult ADHD Self-Report Scale (ASRS)-Expanded Version (ASRS) (Utsun et al., 2017) scores ranged from 0 to 72. Executive Function Index (EFI) (Spinella, 2005) scores ranged from 62 to 157. Pittsburgh Sleep Quality Index (PSQI) (Buysse et al., 1989) scores ranged from 0 to 17. Weiss Functional Impairment Rating Scale – Self Report (WFIRS-S; Weiss, 2000) scores ranged from 0 to 170. Refer to Table 1 below for means and standard deviations.

Review of General Relations in Data Set

Correlational analyses were conducted and supported our predictions for general relationships between variables. Table 1 includes measure correlations. These results also confirm findings reported in current literature that higher executive function is related with fewer ADHD symptoms, better sleep is related with less impairment and fewer ADHD symptoms, and that higher executive function is related with less impairment.

Table 1

Descriptive Statistics and Correlations for Study Variables

Variable	*n*	*M*	*SD*	1	2	3	4	5	6	7
1. ASRS	215	27.62	14.01	—						
2. EFI	215	116.26	15.01	−.39**	—					
3. PSQI	215	6.64	3.40	.40**	−.15*	—				
4. WFIRS-S	215	44.59	32.48	.65**	−.49**	-.41**	—			

*$p < .05$. **$p < .01$.

A regression was conducted to examine the value of ADHD symptoms, executive function, and sleep for predicting impairment. The regression demonstrated that ADHD symptoms, executive function, and sleep accounted for a significant proportion of the variance in impairment F (3, 211) = 74.47, $p < .001$, $R^2 = .51$. ADHD symptoms alone accounted for 42% of variance in impairment. Including executive function and sleep accounted for an additional 9% of variance. Collinearity statistics were within normal limits, suggesting valid results. Additionally, two mediation analyses were conducted to examine the effects of executive function and sleep individually. A mediation analysis demonstrated that ADHD symptoms significantly predict impairment, $b = 1.21$, $p < .001$, [.97, 1.45], and executive function significantly predicts impairment even with ADHD symptoms in the model, $b = -.62$, $p < .001$, [-.84, -.39]. This also indicates that impairment declines as executive function increases and vice versa. Indirect effects also indicate that executive function serves as a mediator of the relationship between ADHD symptoms and impairment, $b = 0.25$, [.13, .41]. A second analysis demonstrated that sleep significantly predicts impairment even with ADHD symptoms in the

model, b = -1.68, p = .002, [-2.73, -.64]. this analysis also demonstrated that sleep functions as a mediator between ADHD symptoms and impairment b = 0.16, [.07, .26]

Primary Hypothesis

Hypothesis 2 expected that sleep would moderate the indirect association between ADHD symptoms and impairment via executive function. Specifically, moderated mediation would be established if the path between executive function and impairment was moderated by sleep (Hayes, 2013). Overall, the model demonstrated that ADHD symptoms, executive function, and sleep accounted for a significant proportion of the variance in impairment F (5, 209) = 45.75, p < .001, R^2 = .52. There was a significant main effect of ADHD symptoms on impairment, b = 1.07, p < .001, [.60, 1.54], and this effect was not moderated by sleep b = -.00, p > .05. However, this effect was moderated by executive function b = -.02, p < .001, [-.03, -.01]. For individuals with higher executive function the effect of ADHD symptoms on impairment is significant b = .79, p < .001 [.46, 1.12]. However, the effect of symptoms on impairment was much stronger among individuals with lower executive function b = 1.40, p < .001 [1.15, 1.66]. There was a significant main effect of ADHD symptoms on executive function b = -.28, p = .04, [-.55, -.02], and this effect was not moderated by sleep b = -.01, p > .05. There was a significant main effect of sleep on impairment b = 8.42, p = .05, [.06, 16.77]. The effect of executive function on impairment was not significant b = -.24, p = .31, [-.71, .22], and this path was not moderated by sleep b = -.06, p = .08, [-.12, .01]. However, further analysis indicates that individuals reporting more sleep problems, low executive function has a strong effect on impairment b = -.80, p < .001 [-1.11, -.49]. For individuals reporting fewer sleep problems, the

effect of executive function on impairment is much weaker but still significant b = -.41, p = .01, [-.72, -.10]. Together these indicate that sleep has a significant moderating effect. (See Figure 2)

Indirect effects were evaluated and revealed that the indirect effect of ADHD symptoms on impairment via executive function was moderated by sleep. Specifically, the bias-corrected percentile bootstrap results produced a moderated mediation index value of b = .12, SE = .04, 95% CI = [.06, .20]. For individuals reporting fewer sleep problems, ADHD symptoms had an indirect effect on impairment via executive function b = .07, SE = .04, CI = [.01, .16]. In contrast, the indirect effect was much stronger for individuals reporting a greater number of sleep issues b = .21, SE = .07, CI = [.08, .36].

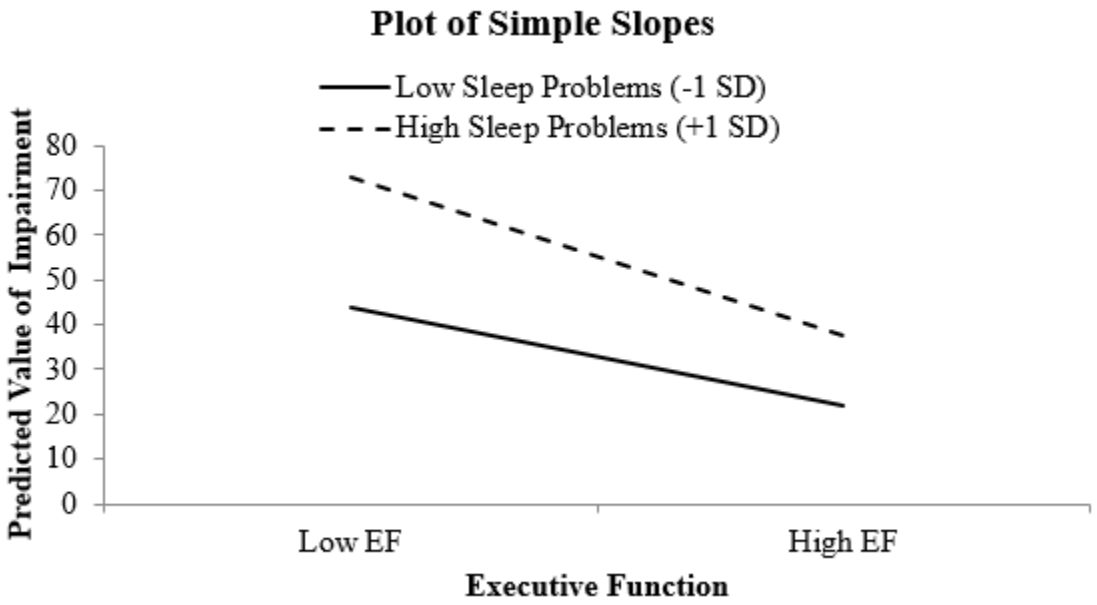

Figure 2. *Differences in impairment between low EF, high EF, low sleep problems and high sleep problems illustrated. Note: low sleep problems and high EF individuals appear to experience the least amount of impairment.*

CHAPTER IV

DISCUSSION

The results of the present study supported general predictions and our primary analysis using Hayes's PROCESS Model 59 supported predictions about mediating and moderating roles of executive function and sleep. Importantly, results further established executive function as an important variable affecting the relation between ADHD symptoms and impairment, and identified the dominant path through which moderation takes place, and demonstrating that sleep moderates the relation between executive function and impairment specifically.

Predictions about general relations were supported, adding to the body of evidence in literature identifying ADHD symptoms, executive function, and sleep as variables that significantly affect impairment in ADHD adults. Individually, ADHD symptoms, executive function, and sleep can contribute to a decreased ability to function in daily roles, affect both cognitive and emotional functioning, physical health, and overall life quality (Barkley et al., 2006; Barkley et al, 2015; Crescioni et al., 2011; Miller et al., 2011; Riggs et al., 2010; Willcut et al., 2015; Wong et al., 2013). A greater number of symptoms, lower executive function, and poor sleep was all associated with greater impairment whereas fewer symptoms, higher executive function, and better sleep was associated with decreased impairment. Important to this study, relations between ADHD symptoms, executive function, and sleep add validating evidence to previous research as results indicate that higher executive function and better sleep are associated

with fewer symptoms or decreased symptom severity (Bijlenga et al., 2013; Bjorvatn, 2017; Dorr & Armstrong, 2018). Additionally, results indicate that sleep and executive function have an important relation to consider when conceptualizing and assessing adult ADHD, collaborating previous findings that sleep is positively related to executive function in general, with better sleepers reporting higher executive function (Jackson et al., 2013; Kuula et al., 2018; Lo et al., 2012). Together these general relations distinguish ADHD symptoms, executive function, and sleep and distinct variables that affect impairment directly, and affect each other. Considering this, our results documenting the moderating effect of sleep on the path between executive function and impairment is important to integrate into adult ADHD conceptualization and for clinical assessment.

The primary goal of this study was to explore the moderating effect of sleep on the indirect relation between ADHD symptoms and impairment via executive function. Results indicated that sleep moderates only the path between executive function and impairment. The relationship between executive function and impairment was much weaker among individuals reporting better sleep than among individuals reporting worse sleep. Research has established that sleep affects executive function (Jackson et al., 2013; Kuula et al.; Lo et al., 2012) suggesting sleep may serve as a protective factor against impairment directly by ensuring individuals have the physical energy to fulfill their life roles and respond to daily demands. Indirectly, better sleep may serve as a protective factor against impairment, allowing individuals to more easily respond to cognitive demands and engage executive function skills that help them avoid impairment. Considering this in the context of the general relation between these variables, with better sleep being positively related with higher executive function, these findings provide

important evidence that clinicians assessing adult ADHD should assess sleep in addition to symptoms and executive function. This practice during clinical assessment will decrease false positives and provide clinicians alternative explanatory evidence for recorded impairments, improve case conceptualization, and result in more impactful interventions.

Strengths and Limitations

One strength of the study is the size of the sample collected, as it allowed researchers to interpret results of the regression-based analyses with confidence they are adequately powered. Although other studies have investigated the relations between ADHD symptoms, executive function, impairment, and sleep, this study is the first known to combine each of these variable as we have done in an attempt to better understand the nature of impairment among adult ADHD individuals. Researchers report that samples recruited via MTurk are closer to being representative of the general population of the United States (Strickland & Stoops, 2018), thus our results are more generalizable than in previous studies based only on college samples.

However, results of this study must be considered within the context of several limitations. To begin, although analysis indicated that the model used in this study was a good fit, this study relied on self-report measures. Although measures used in this study have been previously demonstrated to produce valid data, other research reports that individuals diagnosed with ADHD trend to underreport symptoms, and individuals who have never been diagnosed with ADHD trend to over report symptoms (Sibley et al., 2012). Another limitation of the current study is use of cross-sectional design and the inability to make causal statements about variables. Although the model used in this research allows for contemporaneous predictions, researchers

are restricted from presenting temporal predictions. Future research using laboratory based, and peer report measures of variables to replicate these results. Finally, this study did not examine relations between variables in subgroups (i.e., ADHD diagnosis vs. no diagnosis).

Implications and Future Directions

Our results add further evidence to existing research that has established executive function as both independent of ADHD symptoms (Barkley, 2015), and important in conceptualizing and assessing for adult ADHD (Willcutt et al., 2015). This research also supports existing literature documenting that individuals with higher executive function experience significantly less severe impairment (Barkley & Murphy, 2010; Wåhlstedt, Thorell, & Bohlin, 2008). Results of the current study indicate additional benefits to researchers and clinicians in assessing sleep in addition to traditional variables (i.e., ADHD symptoms, and executive function) due to its potential explanatory value when conceptualizing impairment and primary causal factors. For example, when conceptualizing adult ADHD related impairment, and considering these results have demonstrated that executive function moderates the relation between ADHD symptoms and impairment, and sleep moderates the relation between executive function and impairment, it will be important to consider if sleep is contributing directly to impairment and/or if sleep is exacerbating executive function related impairment. Because of the potential for sleep to worsen executive function related impairment, it appears a crucial assessment target that will reduce the number of misdiagnoses and false positive adult ADHD diagnoses. Overall, results of this study suggest good sleep may serve as a robust protective factor against impairment via multiple paths.

Considering the nature of this research use of clinical samples in future research may reveal additional insight into relations among ADHD symptoms, executive function, and sleep as well as how they interact and affect impairment among adults with ADHD. Likewise use of laboratory based executive function measures and use of peer report in future studies may be productive for research aiming to examine the relation between executive function and ADHD in general, and its relation to sleep and impairment more specifically. Future studies using the current data set can examine convergent validity between executive function items included in the e Adult ADHD Self-Report Scale (ASRS)-Expanded Version and the Executive Function Index (Spinella, 2005). The current project and future research stemming from it may contribute to a greater understanding of ADHD in emerging adulthood, particularly the moderating role of sleep and why sleep may contribute to a higher number of false positive ADHD diagnoses among adults, and can reduce ADHD related impairment by informing future assessments and interventions.

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APPENDIX A

MEASURES

ADHD Self-Report Scale (ASRS) v1.1 Symptom Checklist - Expanded

For each item, circle the number in the column that best describes how you have felt and conducted yourself over the **past one month.**

		Never	Rarely	Sometimes	Often	Very Often
1	How often do you have trouble wrapping up the final details of a project, once the challenging parts have been done?	0	1	2	3	4
2	How often do you have difficulty getting things in order when you have to do a task that requires organization?	0	1	2	3	4
3	How often do you have problems remembering appointments or obligations?	0	1	2	3	4
4	When you have a task that requires a lot of thought, how often do you avoid or delay getting started?	0	1	2	3	4
5	How often do you fidget or squirm with your hands or feet when you have to sit down for a long time?	0	1	2	3	4
6	How often do you feel overly active and compelled to do things, like you were driven by a motor?	0	1	2	3	4
7	How often do you make careless mistakes when you have to work on a boring or difficult project?	0	1	2	3	4
8	How often do you have difficulty keeping your attention when you are doing boring or repetitive work?	0	1	2	3	4
9	How often do you have difficulty concentrating on what people say to you, even when they are speaking to you directly?	0	1	2	3	4
10	How often do you misplace or have difficulty finding things at home or at work?	0	1	2	3	4
11	How often are you distracted by activity or noise around you?	0	1	2	3	4
12	How often do you leave your seat in meetings or other situations in which you are expected to remain seated?	0	1	2	3	4
13	How often do you feel restless or fidgety?	0	1	2	3	4
14	How often do you have difficulty unwinding and relaxing when you have time to yourself?	0	1	2	3	4
15	How often do you find yourself talking too much when you are in social situations?	0	1	2	3	4
16	When you're in a conversation, how often do you find yourself finishing the sentences of the people you are talking to, before they can finish them themselves?	0	1	2	3	4

		Never	Rarely	Sometimes	Often	Very Often
17	How often do you have difficulty waiting your turn in situations when turn-taking is required?	0	1	2	3	4
18	How often do you interrupt others when they are busy?	0	1	2	3	4
19	How often do you waste or mismanage time?	0	1	2	3	4
20	How often do you have trouble making a plan and sticking to it when you are in a situation where planful behavior is needed?	0	1	2	3	4
21	How often do you difficulty prioritizing work when you are in a situation where setting priorities is needed?	0	1	2	3	4
22	How often do you depend on others to keep your life in order and attend to details?	0	1	2	3	4
23	How often do you put things off until the last minute?	0	1	2	3	4
24	How often is it hard for you to complete tasks in the allotted time?	0	1	2	3	4
25	How often do you have trouble remembering the main idea in things that you have read?	0	1	2	3	4
26	How often do you find that your mood is easily changeable?	0	1	2	3	4
27	How often do you feel more easily hassled or overwhelmed than other people in your situation?	0	1	2	3	4
28	How often do you have a hard time controlling your temper?	0	1	2	3	4
29	How often are your feelings easily hurt when you are criticized?	0	1	2	3	4
30	How often do you feel you lack self-discipline?	0	1	2	3	4
31	How often do you have a hard time keeping track of several things at once?	0	1	2	3	4
32	How often do you bore easily?	0	1	2	3	4
33	How often do you act without thinking through possible consequences?	0	1	2	3	4
34	How often are you impatient in conversations or when driving?	0	1	2	3	4

WEISS FUNCTIONAL IMPAIRMENT RATING SCALE – SELF REPORT (WFIRS-S)

Work: ☐ Full time ☐ Part time ☐ Other _____ School: ☐ Full time ☐ Part time

Circle the number for the rating that best describes how your emotional or behavioural problems have affected each item in the last month.

		Never or not at all	Sometimes or somewhat	Often or much	Very often or very much	n/a
A	**FAMILY**					
1	Having problems with family	0	1	2	3	n/a
2	Having problems with spouse/partner	0	1	2	3	n/a
3	Relying on others to do things for you	0	1	2	3	n/a
4	Causing fighting in the family	0	1	2	3	n/a
5	Makes it hard for the family to have fun together	0	1	2	3	n/a
6	Problems taking care of your family	0	1	2	3	n/a
7	Problems balancing your needs against those of your family	0	1	2	3	n/
8	Problems losing control with family	0	1	2	3	n/a
B	**WORK**					
1	Problems performing required duties	0	1	2	3	n/a
2	Problems with getting your work done efficiently	0	1	2	3	n/a
3	Problems with your supervisor	0	1	2	3	n/a
4	Problems keeping a job	0	1	2	3	n/a
5	Getting fired from work	0	1	2	3	n/a
6	Problems working in a team	0	1	2	3	n/a
7	Problems with your attendance	0	1	2	3	n/a
8	Problems with being late	0	1	2	3	n/a
9	Problems taking on new tasks	0	1	2	3	n/a
10	Problems working to your potential	0	1	2	3	n/a
11	Poor performance evaluations	0	1	2	3	n/a
C	**SCHOOL**					
1	Problems taking notes	0	1	2	3	n/a
2	Problems completing assignments	0	1	2	3	n/a
3	Problems getting your work done efficiently	0	1	2	3	n/a
4	Problems with teachers	0	1	2	3	n/a
5	Problems with school administrators	0	1	2	3	n/a
6	Problems meeting minimum requirements to stay in school	0	1	2	3	n/a
7	Problems with attendance	0	1	2	3	n/a
8	Problems with being late	0	1	2	3	n/a
9	Problems with working to your potential	0	1	2	3	n/a
10	Problems with inconsistent grades	0	1	2	3	n/a
D	**LIFE SKILLS**					
1	Excessive or inappropriate use of internet, video games or TV	0	1	2	3	n/a
2	Problems keeping an acceptable appearance	0	1	2	3	n/a
3	Problems getting ready to leave the house	0	1	2	3	n/a
4	Problems getting to bed	0	1	2	3	n/a
5	Problems with nutrition	0	1	2	3	n/a

		Never or not at all	Sometimes or somewhat	Often or much	Very often or very much	n/a
6	Problems with sex	0	1	2	3	n/a
7	Problems with sleeping	0	1	2	3	n/a
8	Getting hurt or injured	0	1	2	3	n/a
9	Avoiding exercise	0	1	2	3	n/a
10	Problems keeping regular appointments with doctor/dentist	0	1	2	3	n/a
11	Problems keeping up with household chores	0	1	2	3	n/a
12	Problems managing money	0	1	2	3	n/a
E	**SELF-CONCEPT**					
1	Feeling bad about yourself	0	1	2	3	n/a
2	Feeling frustrated with yourself	0	1	2	3	n/a
3	Feeling discouraged	0	1	2	3	n/a
4	Not feeling happy with your life	0	1	2	3	n/a
5	Feeling incompetent	0	1	2	3	n/a
F	**SOCIAL**					
1	Getting into arguments	0	1	2	3	n/a
2	Trouble cooperating	0	1	2	3	n/a
3	Trouble getting along with people	0	1	2	3	n/a
4	Problems having fun with other people	0	1	2	3	n/a
5	Problems participating in hobbies	0	1	2	3	n/a
6	Problems making friends	0	1	2	3	n/a
7	Problems keeping friends	0	1	2	3	n/a
8	Saying inappropriate things	0	1	2	3	n/a
9	Complaints from neighbours	0	1	2	3	n/a
G	**RISK**					
1	Aggressive driving	0	1	2	3	n/a
2	Doing other things while driving	0	1	2	3	n/a
3	Road rage	0	1	2	3	n/a
4	Breaking or damaging things	0	1	2	3	n/a
5	Doing things that are illegal	0	1	2	3	n/a
6	Being involved with the police	0	1	2	3	n/a
7	Smoking cigarettes	0	1	2	3	n/a
8	Smoking marijuana	0	1	2	3	n/a
9	Drinking alcohol	0	1	2	3	n/a
10	Taking "street" drugs	0	1	2	3	n/a
11	Sex without protection (birth control, condom)	0	1	2	3	n/a
12	Sexually inappropriate behaviour	0	1	2	3	n/a
13	Being physically aggressive	0	1	2	3	n/a
14	Being verbally aggressive	0	1	2	3	n/a

INSTRUCTIONS:

The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions.

During the past month,

1. When have you usually gone to bed? _____
2. How long (in minutes) has it taken you to fall asleep each night? _____
3. What time have you usually gotten up in the morning? _____
4. A. How many hours of actual sleep did you get at night? _____
   B. How many hours were you in bed? _____

5. During the past month, how often have you had trouble sleeping because you	Not during the past month (0)	Less than once a week (1)	Once or twice a week (2)	Three or more times a week (3)
A. Cannot get to sleep within 30 minutes				
B. Wake up in the middle of the night or early morning				
C. Have to get up to use the bathroom				
D. Cannot breathe comfortably				
E. Cough or snore loudly				
F. Feel too cold				
G. Feel too hot				
H. Have bad dreams				
I. Have pain				
J. Other reason (s), please describe, including how often you have had trouble sleeping because of this reason (s):				
6. During the past month, how often have you taken medicine (prescribed or "over the counter") to help you sleep?				
7. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?				
8. During the past month, how much of a problem has it been for you to keep up enthusiasm to get things done?				
9. During the past month, how would you rate your sleep quality overall?	Very good (0)	Fairly good (1)	Fairly bad (2)	Very bad (3)

Scoring

Component 1	#9 Score	C1 _____
Component 2	#2 Score (<15min (0), 16-30min (1), 31-60 min (2), >60min (3)) + #5a Score (if sum is equal 0=0; 1-2=1; 3-4=2; 5-6=3)	C2 _____
Component 3	#4 Score (>7(0), 6-7 (1), 5-6 (2), <5 (3)	C3 _____
Component 4	(total # of hours asleep) / (total # of hours in bed) x 100 >85%=0, 75%-84%=!, 65%-74%=2, <65%=3	C4 _____
Component 5	# sum of scores 5b to 5j (0=0; 1-9=1; 10-18=2; 19-27=3)	C5 _____
Component 6	#6 Score	C6 _____
Component 7	#7 Score + #8 score (0=0; 1-2=1; 3-4=2; 5-6=3)	C7 _____

Add the seven component scores together _____ ***Global PSQI*** _____

A total score of "5" or greater is indicative of poor sleep quality.
If you scored "5" or more it is suggested that you discuss your sleep habits with a healthcare provider

Scale		*Rate how well each of the following statements describes you.*	Not at all		Somewhat		Very much	Valence
MD	1	I have a lot of enthusiasm to do things.	1	2	3	4	5	
ORG	2	When doing several things in a row, I mix up the sequence	1	2	3	4	5	Inverted
SP	3	I try to plan for the future	1	2	3	4	5	
MD	4	I can sit and do nothing for hours.	1	2	3	4	5	Inverted
IC	5	I take risks, sometimes for fun.	1	2	3	4	5	Inverted
ORG	6	I have trouble when doing two things at once, multi-tasking	1	2	3	4	5	Inverted
MD	7	I'm interested in doing new things.	1	2	3	4	5	
EM	8	I have a lot of concern for the well being of other people.	1	2	3	4	5	
SP	9	I'm an organized person.	1	2	3	4	5	

SP	10	I save money on a regular basis.	1	2	3	4	5	
IC	11	I do or say things that others find embarrassing.	1	2	3	4	5	Inverted
EM	12	People who are foolish enough to be taken advantage of deserve it.	1	2	3	4	5	Inverted
SP	13	I only have to make a mistake once in order to learn from it.	1	2	3	4	5	Inverted
MD	14	I tend to be an energetic person.	1	2	3	4	5	
IC	15	I make inappropriate sexual advances or flirtatious comments.	1	2	3	4	5	Inverted
EM	16	When someone is in trouble, I feel the need to help them.	1	2	3	4	5	
ORG	17	I sometimes I lose track of what I'm doing.	1	2	3	4	5	Inverted
EM	18	I feel protective towards a friend who is being treated badly.	1	2	3	4	5	

SP	19	I think about the consequences of an action before I do it.	1	2	3	4	5	
IC	20	I lose my temper when I get upset.	1	2	3	4	5	Inverted
EM	21	I take other people's feelings into account when I do something.	1	2	3	4	5	
ORG	22	I have trouble summing up information in order to make a decision with it.	1	2	3	4	5	Inverted
ORG	23	I start things, but then lose interest and do something else.	1	2	3	4	5	Inverted
IC	24	I swear/use obscenities.	1	2	3	4	5	Inverted
EM	25	I don’t like it if my actions or words hurt someone else	1	2	3	4	5	
SP	26	I use strategies to remember things.	1	2	3	4	5	
SP	27	I monitor myself so that I can catch any mistakes.	1	2	3	4	5	

Executive Function Index (EFI)

APPENDIX B

APPROVAL LETTER

From:	prm199@msstate.edu
To:	Armstrong, Kevin; McKinney, Cliff; DeShong, Hilary; klm83@msstate.edu; md1207@msstate.edu; Nadorff, Michael
Subject:	Approval Notice for Study # IRB-18-442, Sleep and Executive Function as Predictors of Impairment from ADHD Symptoms
Date:	Friday, November 30, 2018 10:29:02 AM

Protocol ID: IRB-18-442
Principal Investigator: Kevin Armstrong
Protocol Title: Sleep and Executive Function as Predictors of Impairment from ADHD Symptoms
Review Type: EXEMPT
Approval Date: November 30, 2018
Expiration Date:November 29, 2023

The above referenced study has been approved. To access your approval documents, log into myProtocol and click on the protocol number to open the approved study. Your official approval letter can be found under the Event History section. For non-exempt approved studies, all stamped documents (e.g., consent, recruitment) can be found in the Attachment section and are labeled accordingly.

If you have any questions that the HRPP can assist you in answering, please do not hesitate to contact us at irb@research.msstate.edu or 662.325.3994.