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DISTURBED SLEEP AND ADHD

Philadelphia College of Osteopathic Medicine

Department of Psychology

THE IMPACT OF DISTURBED SLEEP ON ATTENTION, WORKING MEMORY,
AND REACTION TIME TASKS IN CHILDREN WITH ADHD

By Kathryn Robb, M.A., M.S.

Submitted in Partial Fulfillment of the Requirements for the Degree of

Doctor of Psychology

May 2015

**PHILADELPHIA COLLEGE OF OSTEOPATHIC MEDICINE
DEPARTMENT OF PSYCHOLOGY**

Dissertation Approval

This is to certify that the thesis presented to us by Kathryn Robb
on the 11th day of May, 2015, in partial fulfillment of the
requirements for the degree of Doctor of Psychology, has been examined and is
acceptable in both scholarship and literary quality.

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Abstract

Attention deficit/hyperactivity disorder is the most commonly diagnosed neurodevelopmental/psychiatric condition in childhood (CDC; Gruber, 2009).

Disturbances in sleep can create a variety of impairments, both cognitive and behavioral, and may negatively affect attention, memory, visuo-spatial abilities, sustained attention and divergent intelligence (creativity) (Stores, 1999). The aim of the present study was to examine the role that sleep disturbances had on the cognitive performance of children with ADHD. Specifically, the possible relationship between poor sleep and children's performance on working memory, attention and reaction time tasks and poor sleep were examined. Overall, in the current sample of 54 children who underwent a neuropsychological evaluation at an outpatient clinic, the presence of sleep disturbances was not predictive of performance on tasks of attention and reaction time and memory. Although these findings seem counter to the existing literature, possible explanations for these discrepancies are provided.

Table of Contents

	Page
Acknowledgements.....	iii
Abstract.....	iv
TABLE OF CONTENTS.....	v
LIST OF TABLES.....	vi
Chapter 1.	
Introduction.....	1
Chapter 2.	
Literature Review.....	6
What is sleep?	7
Physiology of Sleep.....	10
Neurobiology of Sleep and ADHD.....	13
Sleep Deprivation Studies-Adults and Animals.....	19
Sleep Deprivation-Children.....	25
Chapter 3.	
Hypotheses.....	38
Chapter 4.	
Methodology.....	38
Chapter 5.	
Design and Design Justification.....	40
Participants.....	40
Inclusion Criteria.....	41
Measures.....	41
Procedure.....	44
Results.....	45
Discussion.....	46
Limitations.....	50
Future Directions	52
References.....	54

LIST OF TABLES

	Page
Table 1 Subscale Data Information.....	46

CHAPTER 1

Introduction

Statement of the Problem

It is estimated that attention-deficit/hyperactivity disorder (ADHD) occurs in approximately 3% to 7.5% of school-aged youth, making it one of the most prevalent psychiatric conditions diagnosed in children (CDC; Gruber, 2009). Characterized most commonly by impulsivity/hyperactivity and inattention, children with ADHD typically demonstrate deficits in executive functioning, including working memory, inhibition, planning and sustained attention (American Psychiatric Association, 2000). Four types of ADHD are outlined in the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV): “predominantly inattentive,” “predominantly hyperactive-impulsive,” “combined,” and “not otherwise specified (NOS).” Labeled a “serious public health problem” by the Centers for Disease Control and Prevention, ADHD is associated with significant impairment across several domains, including socialization and school performance; untreated, individuals with ADHD struggle in many crucial areas during their lifetimes (Gruber, 2009).

The impact of sleep on health and development is a crucial, yet often overlooked area of functioning in children. Some researchers posit the hypothesis that the effects of poor sleep in children may manifest as behavioral symptoms rather than fatigue, although this phenomenon is not well understood (Paavonen et al., 2009). The signs of sleepiness in children may differ entirely from those observed in adults; that is, instead of a reduction in activity and an increase in overt signs of sleepiness, children suffering from sleep disturbances may exhibit an increase in activity and inattention, or symptoms of

ADHD (Paavonen et al., 2009; Stores, 1999). Dahl (1996) speculates that there exists a sub-group of children inaccurately diagnosed with ADHD; in fact, the primary problem is actually a sleep disorder.

The effects of poor sleep on children's emotional, social, physical and cognitive functioning are vast, yet much of what is presumed about sleep and functioning in children is gleaned from adult literature. This is due largely in part to the ethical concerns inherent in studying sleep in children, because many will argue that depriving a child's sleep for research purposes poses numerous dilemmas. Still, the interest in the effects of disordered sleep in children is growing as more is understood about its developmental significance.

Emotional and social development may be negatively affected by poor sleep. According to the Centers for Disease Control (CDC), "Parents of children with a history of ADHD report almost 3 times as many peer problems as those without a history of ADHD (21.1% vs. 7.3%)"; parents also report that "Children with a history of ADHD are almost 10 times as likely to have difficulties that interfere with friendships (20.6% vs. 2.0%)." Mothers of children with learning disabilities and comorbid sleep disturbances are observed to be less affectionate towards their children, and use more physical forms of punishment than mothers of children with learning disabilities and no sleep problems (Quine, 1992). Sleep problems may also cause indirect emotional disturbances in children, because sleep disorder phenomena can be frightening (e.g., intense hypnagogic imagery), or embarrassing (e.g., sleep walking or night terrors) (Stores, 1999). Mood, according to a meta-analysis conducted by Pilcher and Huffcut (1996) has been determined to be even more negatively affected by lack of sleep than cognition or motor

performance. Physical effects of poor sleep have been reported, and there is growing interest in the effects of poor sleep on the immune system (Stores, 1999).

With regards to cognition, the main focus of the proposed study, sleep disturbance can create a wide range of impairments, and may negatively affect attention, memory, visuo-spatial abilities, sustained attention and divergent intelligence (creativity) (Stores, 1999). Although there is increasing interest in the effects that disordered sleep has on cognitive functioning in children, few studies have critically examined this phenomenon. There are far more studies focusing on disordered sleep in adults, and of the studies that focus on children, most are examining the effects of disordered sleep in children with breathing disorders, such as obstructive sleep apnea. Studies have demonstrated that, in adults, tasks engaging the frontal lobe, thus requiring divergent, complex or creative thinking (prefrontal functions) are the most significantly impacted by sleep deprivation (Dahl, 1996).

It is understood that working memory and attention are understood to involve the frontal lobe; thus, extrapolating from the studies conducted on adults, the proposed study seeks to examine the impact of disordered sleep on both constructs in children with ADHD. It should be noted that children with ADHD are presumed to possess inherent deficits in these areas as a function of their disorder; what is unclear, at least from a research standpoint, is what the effects on disordered sleep will be on the prefrontal functioning of children who are already compromised in that area.

There is a marked paucity of controlled studies examining the cognitive sequelae of poor sleep in children with an ADHD diagnosis. Among children and adolescents with an existing diagnosis of ADHD, sleep problems are reported to be an estimated 25% to

50%. Thus, it is logical to assume that there is some relationship between sleep problems and ADHD, though the nature of this relationship has not been heavily researched. Sleep problems are understood to be common among children with ADHD; however, the understanding of the association between ADHD and sleep disturbance is limited (Gruber, 2009); even less is understood about the negative effects of poor sleep on the specific cognitive functions of attention and working memory of children with ADHD.

Although the literature remains mixed about the effects of disordered sleep on working memory, a study by Karpinski et al. (2008) found that the risk of working memory impairments increased as the severity of sleep-disordered breathing increased. A majority of the research on the cognitive sequelae of disordered sleep was conducted on the OSA population; there is little literature examining the impact of disordered sleep on the working memory abilities of children with ADHD without OSA or night time movement disorders such as restless leg syndrome (RLS), or periodic limb movement disorder (PLMD). As with the construct of attention, it is hypothesized that impairments in working memory will also be noted among children suffering from disordered sleep.

If, through the course of empirical research, clinicians are better able to identify and differentiate behavioral issues related to poor sleep and/or ADHD, it is hoped that treatment outcomes will likely improve for both conditions. Investigating differences in attention and working memory as a function of disordered sleep is one piece of that puzzle, and may lead to a greater understanding of the specific ways in which children with ADHD are affected by poor sleep. It would be helpful for clinicians to be made aware of the overlap between poor sleep and behavior commonly associated with ADHD; with increased awareness of the association between the two will likely

come a better ability to diagnose and treat both disorders appropriately. Moreover, sleep may be thought of as a more pragmatic domain for intervention, and instilling proper sleep hygiene may be a worthwhile initial focus of treatment if sleep problems are suspected (Dahl & Harvey, 2007).

Purpose of the Study

It is hoped that, through the course of this study, a better understanding of the specific kinds of deficits experienced by children with ADHD and disordered sleep will be achieved. From a neurobiological perspective, understanding the complex relationship of disordered sleep and ADHD may aid in the successful management of both conditions, and may help clinicians with the diagnostic and treatment processes. Thus, the importance of assessing for and understanding sleep in children and adolescents as it relates to ADHD will be the focus of the present study. The overarching goal of the study is to examine the impact of disordered sleep on the constructs of working memory and attention in a group of children with ADHD. A more specific understanding about the impact that sleep has on children with ADHD holds clinical significance, and may assist clinicians in the diagnostic and treatment processes.

Overall, the impact of poor sleep on children's development is thought to be great, yet little is known about the effects of poor sleep on the constructs of attention and working memory in children with ADHD despite the undeniably high comorbidity rate. Much of what is assumed about children's cognitive functioning comes from studies conducted on adults (Gruber & Sadeh, 2003) although useful information has emerged from literature examining the impact of disordered breathing and movement disorders on children's cognitive functioning (Gruber et al., 2010; Biggs et al., 2011). The findings of

these studies, in addition to the small body of literature focusing on children without breathing or movement disorders will be extrapolated to lay the basis for the present study.

CHAPTER 2

Literature Review

The American Psychological Association (APA) reports that 40 million Americans suffer from over 70 different sleep disorders, with approximately 60% of adults reportedly suffering from some kind of sleep problem several nights per week. Furthermore, sleep problems seem to be more prevalent in the pediatric population, with approximately 69% of children experiencing a sleep problem at least a few nights per week (<http://www.apa.org/topics/sleep/why.aspx>). Data also show that 25% to 50% of children and adolescents with attention deficit/hyperactivity disorder (ADHD) suffer from disordered sleep, and in particular tend to experience difficulties initiating and maintaining sleep (Gruber, 2010).

ADHD is reportedly the most commonly diagnosed psychiatric disorder in children, affecting an estimated 5% to 10% of school-aged children (Cortese et al., 2005). The prevalence and chronicity of ADHD, the significant widespread impairment associated with the disorder, as well as the limited effectiveness of current treatments, has led the Center for Disease Control and Prevention to label ADHD as a “serious public health problem (Gruber, 2009).”

For a formal diagnosis of ADHD, according to the Diagnostic and Statistical Manual- Fourth Edition (2000), onset must occur prior to age 7, and impairments in functioning are required across two or more settings. ADHD is characterized by deficits in executive functioning, including impulsivity, increased motor activity, and decreased attention, although the negative impact of ADHD is often observed in other areas of functioning as well; children and adolescents with ADHD often struggle with academic achievement, social relationships and sleep disturbances.

The present study seeks to elucidate the complex relationship that exists between sleep disorders and the cognitive sequelae of ADHD; it addresses, specifically, the role of sleep disturbances as they relate to attention and working memory functioning in a sample of children with ADHD. The subject of sleep will be briefly introduced before outlining the effects of sleep disorders on the cognitive functioning both of adults and of children. Finally, although the impact of disordered sleep on the cognitive functioning of children with ADHD is, at present, an under-researched area, the existing literature will be reviewed.

What is sleep?

Prior to discussing what previous research has indicated regarding the effects of poor sleep on children's cognitive functioning, it is necessary to understand what is known about sleep in general. Sleep seems to be a commonality across all species and is necessary for survival; however, little is understood about the physiological functions of sleep (Dahl, 1996).

Although the exact function of sleep seems to remain a mystery, its importance during the early years of brain development cannot be denied. Dahl (1996) writes that during the first two years of life, sleep appears to be the brain's primary activity; by age two, the average child has spent 10,000 hours sleeping and approximately 7,500 hours awake. During years two to five, a balance of sleep and wakefulness ensues, and by early school age, the average child has spent more time sleeping than on all other waking activities combined.

The Importance of Sleep.

Colton and Altevogt (2006), in their review of sleep literature, highlight the larger public health problems associated with poor sleep and sleep disorders; over the past hundred years, the amount of time Americans spend sleeping has decreased by 20 percent. They note that the long-term health consequences associated with sleep deprivation and sleep disorders include depression, stroke, heart attack, obesity, hypertension and diabetes, and state that when compared with healthy individuals, those suffering from sleep deprivation tend to have greater healthcare needs, have an increased likelihood of injury (e.g., motor vehicle crashes), and are generally less productive at work. The sequelae of sleep deprivation highlighted in this section refer to basic physiological effects; the effects of poor sleep on neuropsychological functioning will be emphasized in subsequent sections.

Sleep loss is typically defined as periods of sleep that involve less than seven to eight hours per night. In their book, Colton and Altevogt (2006) highlight research demonstrating the deleterious health consequences of a chronic sleep pattern involving chronically fewer than seven hours per night, including the negative effects on cardiovascular, endocrine and immune systems.

With regard to obesity, the authors note that research has demonstrated a dose-response relationship between length of sleep and weight. That is, the worse the sleep, the greater the obesity. A prospective study following 500 adults demonstrated that, by age 27, subjects sleeping fewer than 6.5 hours per night were 7.5 times more likely to have a higher body mass index (Hasler et al., 2004). Studies (Taheri et al., 2004; Spiegel et al., 2004) have also found that decreased levels of leptin, a hormone produced by an

adipose tissue hormone that suppresses appetite, and increased levels of ghrelin, a peptide that stimulates appetite, was associated with chronically poor sleep. These findings seem to highlight the impact of sleep on appetite-regulating hormones, hence the association to obesity.

An increase in the prevalence rates of diabetes has also been associated with chronic sleep loss. Gottlieb et al. (2005) report that individuals sleeping fewer than 5 hours per night had 2.5 times higher rates of diabetes than individuals sleeping 7 to 8 hours per night. Individuals sleeping 6 hours per night were 1.7 times more likely to have diabetes.

Sleep loss is also associated with stroke and cardiovascular morbidity. Ayas et al. (2003) found that sleeping 5 hours or less per night was associated with a 45 percent increase in risk of heart attack (fatal and non-fatal).

An increase in age-specific disease mortality has also been associated with chronically poor sleep. Three large, population-based studies lend support to this conclusion (Kripke et al., 2002; Takashi et al., 2004 & Patel et al., 2004). The studies' cohorts ranged in size from 83,000 to 1.1 million people. Subjects were asked about their sleep duration; they were then followed for periods of 6 to 14 years. The findings were significant: sleep durations of less than 5 hours was associated with 15 percent increased risk of mortality from all causes.

Of note, these studies were conducted on adults; child-specific studies will be presented subsequently. It appears that sleep deprivation across the lifespan is associated with increased mortality from a wide range of physiological causes. Although the mechanism of action relating sleep to mortality is not always understood, the association

persists nonetheless. Thus, the importance of sleep as it relates to physiological functioning cannot be overstated, because research has demonstrated its far-reaching effects; as such, the impact of sleep on behavior and academic functioning is hypothesized to be significant as well.

Physiology of Sleep

There are two types of sleep: non-rapid eye-movement (NREM) and rapid eye-movement (REM). There are four stages of NREM, each representing a continuum of depth and each with its own unique brain wave patterns (Colten & Altevogt, 2006).

REM and NREM sleep cycles alternate cyclically throughout a period of sleep; although reasons for this are not yet understood, it is known that any irregularities in cycling or missing sleep stages are associated with sleep disorders (Colten & Altevogt, 2006). Periods of sleep begin with a quick NREM stage 1, then progresses through stages 2, 3 and 4, and eventually to REM; people do not stay in REM for the remainder of the sleep period, but rather cycle between stages of NREM and REM throughout the duration of sleep. Approximately 75 to 80 percent of sleep is spent in NREM, and REM sleep constitutes the other 20 to 25 percent. The first NREM-REM sleep cycle averages 70 to 100 minutes in length; subsequent cycles are longer lasting, about 90 to 120 minutes (Colten & Altevogt, 2006). According to Colten and Altevogt (2006), normal adults experience an increase in REM sleep as the sleep period progresses; it is at its longest during the last third of the night. As the period of sleep progresses, stage 2 accounts for most of the NREM sleep, and stages 3 and 4 might disappear entirely.

Stages of Sleep

NREM Stage 1.

Colten and Altevogt (2006) refer to stage 1 of NREM sleep as a transitional state, as in individuals without narcolepsy and other specific neurological disorders (and newborns) NREM stage 1 typically lasts only 1 to 7 minutes and constitutes 2 to 5 percent of total sleep. This stage is easily interrupted by noises and other distractions. Electroencephalographic (EEG) recordings during this stage transitions from rhythmic alpha waves (wakefulness) to mixed-frequency waves which are typically low-voltage. Alpha waves are associated with a wakeful, but relaxed, state (Colten & Altevogt, 2006).

NREM Stage 2.

NREM stage 2 sleep lasts from 10 to 25 minutes initially, and lengthens throughout the night to account for approximately 45 to 55 percent of total sleep. During stage 2, individuals require more intense stimulation to awaken. EEG reveals “low-voltage, mixed-frequency activity characterized by the presence of sleep spindles and k-complexes (Colten & Altevogt, 2006).” Colten and Altevogt (2006) write that it is hypothesized that sleep spindles play an important role in memory consolidation, stating that individuals who have just learned a novel task will exhibit significantly more sleep spindles than those in a control group.

NREM Stages 3 and 4: Slow-Wave Sleep.

Stages 3 and 4 are collectively termed slow-wave sleep (SWS); the majority of SWS occurs during the first third of the night (Colten & Altevogt, 2006). Although these two stages are grouped together, they have markedly different characteristics. Stage 3

constitutes 3 to 8 percent of total sleep, and lasts only a few minutes. EEG shows high-voltage, slow-wave brain activity during this time.

Stage 4, the last NREM stage, lasts 20 to 40 minutes and constitutes 10 to 15 percent of total sleep; the arousal threshold is the highest during this stage. EEG shows increased high-voltage, slow-wave activity.

REM Sleep.

REM sleep is characterized by low-voltage, mixed-frequency brain waves, bursts of rapid eye movements, “sawtooth” wave forms, theta activity, slow alpha activity and muscle atonia (loss of muscle tone and reflexes) (Colten & Altevogt, 2006). The initial REM period lasts 1 to 5 minutes, and increases in duration as sleep progresses. Dreaming occurs during REM sleep, and the muscle atonia associated with this stage serves the important function of preventing an individual from acting out his or her dreams or nightmares. According to Colten and Altevogt (2006), approximately 80 percent of vivid dream recall happens after waking from this sleep stage.

Aging and Changes in Sleep Architecture

Sleeping patterns change dramatically and continually throughout the lifespan, and understanding what is typically associated with each stage of life may help determine what kinds of sleep patterns are normal versus what constitutes cause for concern. Generally, individuals tend to sleep less and with decreased efficiency as they age. The focus of the present study is aimed at school-aged children; therefore this section shall focus primarily on that population and the behaviors and challenges typically associated with this group.

By the time a child enters school (typically by age 6), he or she begins to manifest circadian sleep phase preferences, or the tendency to be either a “night owl” or “morning bird” (Colten & Altevogt, 2006). Additionally, beginning around this time children may experience challenges with sleep initiation and maintenance, including the presence of nightmares. Furthermore, Colten and Altevogt (2006) state that the reduction in sleep that occurs as children get older cannot be attributed to a decreasing physiological need alone; social and cultural norms and requirements are to blame for changing sleep patterns as well.

Colten and Altevogt (2006) indicate that adolescents need approximately 9 to 10 hours of sleep nightly, though few report actually meeting this requirement. There exists a complex and bidirectional relationship between the onset of puberty and sleep. Sleep latency and SWS tend to decrease with advancing pubertal development, while time spent in stage 2 increases. It is thought that these changes are due, at least partially, to the hormonal changes that accompany pubertal onset (Colten & Altevogt, 2006). The authors state that, during midpuberty, “There is a significantly greater daytime sleepiness than at earlier stages of puberty (Colten & Altevogt, 2006).” In more mature adolescents, afternoon sleepiness tends to be greater than what is reported in late afternoon and evening.

Basic Neurobiology of Sleep and ADHD

Theories of Central Nervous System Involvement.

Research states that there is an overlap in the central nervous system centers that regulate attention/arousal and those that regulate sleep (Biederman & Spencer, 1999; Dahl, 1996). The possibility exists that disruptions to one system may result in parallel

disturbances in the other (Owens, 2009). Owens (2009), in a review of research on sleep and ADHD in children, outlines some of the prevailing theories about the underlying central nervous system pathology implicated in both.

First, Owens (2009) presents the theory that the prefrontal cortex is the primary area of the brain implicated both in attention and sleep deprivation/disruption; she cites several functional neuroimaging studies that demonstrate metabolic changes observed in the prefrontal cortex in individuals with ADHD and that are similar to those found in individuals after sleep deprivation. She also cited findings from the adult literature, demonstrating the impact on neuropsychological measures of prefrontal cortex functioning, including impairments in working memory and attention (as well as other executive functions), and behavioral inhibition. In addition to the prefrontal cortex, Prehn-Kristensen et al. (2011) add that the cerebellum, striatum and motor areas of the brain are also implicated in ADHD. Thus, thanks to relatively recent advances in neuroimaging technology, connecting sleep and ADHD to one another becomes a matter of science and not simply speculation.

Second, Owens (2009) presents van der Heijden, Smits, van Someren & Gunning's (2005) theory that there exists a primary circadian disruption in individuals with ADHD, which may involve deviations in the normal pattern and timing of melatonin secretion or "responsiveness to environmental cues such as light (Owens, 2009)."

Finally, Owens (2009) presents a theory from a few studies which examined daytime sleepiness and arousal levels in children with ADHD, finding that children with ADHD show an increased sleep propensity (as measured objectively); the theory is that hyperactivity, at least for some children, may actually be an adaptive behavior with the

purpose of counteracting the negative effects of underlying daytime sleepiness and hypoarousal.

Patients with ADHD exhibit prefrontal hypoactivity (Prehn-Kristensen et al., 2011), a fact which may lend support to the hypothesis that children with ADHD may benefit from sleep with respect to cognitive functioning to an even greater degree than normally-developing children, because sleep appears to have restorative effects on these areas of the brain.

Biochemical Implications.

Gruber (2009) underscores the importance of understanding sleep as it pertains to the pathophysiology of ADHD; biochemically, disorders of sleep and ADHD have been associated with disturbances in the noradrenergic and dopaminergic neurotransmitter systems. Studies examining the role of these neurotransmitter actions in children with both sleep disorders and with ADHD are rather limited (Viggiano, Vallone, & Sadile, 2004; Viggiano, Kuocco, Arcieri et al., 2004), but given that the two disorders are associated with the same neurotransmitters, it may be logical to hypothesize that improving sleep may thus improve symptoms of ADHD. Logic may also denote that when a sleep disorder is present in a child, his or her behavior may closely resemble the common behavioral and cognitive sequelae of ADHD.

Sleep and Children with ADHD

The negative impact of sleep problems on children's cognitive functioning has recently become an area of interest for clinicians and parents; as more is understood about the impact of sleep on children's development, there is a need for more information. Indeed, the relationship between sleep and ADHD is a complex one, which

may manifest in a myriad of ways. Sleep problems are frequently reported among children with ADHD, including difficulty initiating and maintaining sleep (Owens, 2009). Owens (2009) has written extensively on the subject, noting that, clinically, sleep-driven problems of ADHD may appear in many forms. She notes that primary sleep disorders, such as obstructive sleep apnea, may produce behavioral symptoms that mimic ADHD during the day, and that comorbid sleep problems could potentially exacerbate the present symptoms of ADHD. In addition, the psychotropic medications that are often used to manage the behavioral symptoms of ADHD may result in sleep problems. Finally, she states that, in some children, problems sleeping may represent an “intrinsic dysregulation of sleep and wakefulness associated with ADHD-related CNS dysfunction (Owens, 2009).”

Therefore, clinically, sleep issues in children with ADHD may present challenges for clinicians in determining the etiology of the disturbed sleep and formulating an effective treatment plan based on this information. For children, sleep problems may have not only a direct and deleterious impact on the daytime symptoms of ADHD, but also on overall quality of life. Because of this, an understanding of the role that sleep plays on the cognition of children with ADHD may lead to more accurate treatment planning.

In a thorough review of existing literature pertaining to disordered sleep and ADHD, Gruber (2009) writes that, in clinical practice, sleep problems reportedly affect an estimated 25% to 50% of patients with ADHD, yet the relationship between ADHD and sleep remains under-researched. It is in the best interest of all parties to investigate the role of sleep, because when steps are taken to remedy a child’s disturbed sleep, quality of life significantly improves for everyone (Gruber, 2009). Building on the idea

that improving sleep may improve overall functioning, a natural progression may be to suggest that improving sleep may decrease the severity of ADHD symptoms.

Sleep Abnormalities in Children with ADHD.

Although studies conducted specifically on the sleeping patterns of children with ADHD are limited, some interesting findings have been reported. Two recent actigraphic studies have found that children with ADHD often had sleep patterns that were unstable, and/or inconsistent in their sleeping and waking times (Gruber, Sadeh & Raviv, 2000; Gruber & Sadeh, 2004). It has also been reported that one third of medication-free children with ADHD have chronic sleep-onset insomnia (Van der Heijden, Smits, Van Someren et al., 2007; Corkum, Moldofsky, Hogg-Johnson et al., 1999; Stein, 1999). Gruber et al (2010) note that other sleep problems commonly associated with ADHD in children include frequent night awakening, bedtime resistance, restless sleep, decreased sleep duration, difficulty waking up in the morning, high levels of nocturnal activity, and unstable/inconsistent sleep patterns.

Goraya et al (2009) sought to describe some of the abnormalities observed on polysomnographs of children with ADHD and sleep disorders, hopefully, to gain a greater understanding of the types of sleep problems associated with ADHD. The researchers found that children with ADHD and comorbid sleeping problems, including obstructive sleep apnea, upper airway resistance syndrome, obstructive hypoventilation, and periodic limb movements of sleep, showed increased wake after sleep onset (an index of insomnia), increased arousal index, and reduced sleep efficiency, which subsequently led to excessive daytime sleepiness, sleep fragmentation, or hyperactivity.

Although the sample used in this study was composed of individuals referred to a sleep clinic by a pediatric neurologist for severe sleep disturbances, and may or may not be generalizable to the general population, the results are nonetheless relevant to clinical practice. Clinicians should be aware that periodic limb movements of sleep and sleep disordered breathing are frequently found among children with ADHD and sleep complaints; these findings add to the rationale for adding sleep questionnaires to neuropsychological evaluations.

Diagnostic Concerns.

The interest in sleep alterations associated with ADHD has increased recently, possibly reflecting clinicians' concerns for improved and more thorough evaluation and treatment of children presenting with both ADHD and with disordered sleep. In light of the undeniably high comorbidity rates of ADHD and sleep problems, this seems to be a natural progression. Various researchers are beginning to investigate the possibility that, in some cases, children may be misdiagnosed as having ADHD, when truly their symptoms are consistent with poor sleeping patterns. Dahl (1996) writes that the behavioral presentation of children suffering from disordered sleep looks markedly different from sleep-deprived adults; specifically, he states that toddlers and early school-aged children respond to sleep deprivation with irritability, low frustration tolerance, crankiness and short attention spans. Further, he states that many clinicians are beginning to comment on the cognitive and behavioral changes manifested by sleep-deprived children and their remarkable similarity to the behaviors commonly associated with ADHD.

Although it has been reported that the various subtypes of ADHD may be associated with different sleeping issues, the findings are quite mixed and are outside the scope of this study, because the goal of this study is not to delineate sleep patterns associated with the different subtypes but rather to examine the association between poor sleep and performance on cognitive functioning tasks. This is a topic, however, which may serve as an interesting and important next step in the research on sleep disorders and ADHD in children.

Although literature exploring the relationship between disordered sleep on children with an ADHD diagnosis is limited, a logical place to begin examining the effects of poor sleep (or sleep deprivation) on cognitive and behavioral functioning would be to examine studies conducted on adults. They are greater in number and experimenters may circumvent the ethical and moral dilemmas often encountered when child-subjects are involved. While findings obtained from adult subjects may not hold entirely consistent with children; however, examining the literature provides a framework and a rationale for conducting similar research with children. Therefore, a review of adult sleep-deprivation literature is offered prior to delving into the research concerning the effects of disturbed sleep on children.

Effects of Sleep Deprivation in Animals and Adults

In an attempt to discover the function of sleep, a logical research strategy would be to take it away and observe the consequences. This approach has been utilized in animal studies, as well as on human subjects. Sleep deprivation has been lethal in rats; in numerous controlled studies, it has been demonstrated that rats may survive as long

without sleep as they can without food (Rechtschaffen, Bergmann & Everson, 1989; Everson, Bergman & Rechtschaffen, 1989).

The effects of sleep deprivation have been studied extensively in adults, as well. Methodologies for exploring the impact of sleep deprivation have included total sleep deprivation, partial sleep deprivation, and differential sleep stage deprivation, or depriving subjects of REM or delta sleep (Dahl, 1996).

Adult Sleep Literature.

With regard to sleep problems reported in the adult literature, Gruber (2009) states that up to 83% of assessed adults report sleep problems on questionnaires. In studies in which actigraph technology was used to measure specific sleep issues, researchers found that adults with ADHD exhibited longer sleep onset latency, reduced sleep efficiency, and a reduced average duration of uninterrupted sleep periods (Dodson & Zhang, 1999; Kooj, Aeckerlin & Buitelaar, 2001; Schredl, Alm & Sobanski, 2007; Kooji, Huub, Middlekoop et al., 2001; Philipsen, Feige, Hesslinger et al., 2005; Philipsen, Hornyak & Riemann, 2006).

Much can be learned from literature concerning breathing disorders; patients with chronic breathing disorders, such as snoring and obstructive sleep apnea (OSA), consistently report difficulty sleeping, and in-turn an increase in daytime sleepiness (Tassi et al., 2011). In addition, nighttime movement disorders, including periodic limb movement disorder, may provide useful information pertinent to the child population as well.

Nocturnal Breathing Disorders

Snoring.

Tassi et al. (2012) sought to examine the impact of sleep deprivation on daytime alertness and cognitive performance in snorers and non-snorers. Approximately 40 percent of men and 20 percent of women report regular snoring (Tassi et al., 2012). The occurrence of respiratory events, including snoring, is associated with micro arousals in sleep to release upper airway resistance, resulting in fragmented sleep; Tassi et al. (2012) hypothesize that such sleep fragmentation may result in daytime sleepiness even in snorers who do not suffer apneic episodes. Although excessive daytime sleepiness (EDS) is often assumed to stem from obstructive sleep apnea syndrome, clinical investigation suggests this is not always the case. EDS may occur even in healthy snorers (non-apneic); thus, this suggests that isolated snoring may cause disturbances in sleep which produce EDS. Further, Tassi et al. (2012) suggest that such nocturnal breathing disorders, such as snoring, may worsen over time due to chronic sleep deprivation, resulting in a negative cycle.

Tassi et al. (2012) designed their study to compare both objective and subjective daytime sleepiness as well as cognitive performance among healthy, young snorers and non-snorers following periods of total acute or partial chronic deprivation of sleep. The authors had a sample of sixteen healthy males, eight of whom were snorers and eight were non-snorers. Sleepiness was measured objectively, using the mean sleep latency test (MSLT), and subjectively, using the Karolinska Sleepiness Scale (KSS). Subjects' reaction time was assessed using the Psychomotor Vigilance Test.

The authors found that sleep deprivation alone did not enhance snoring; however,

objective daytime sleepiness was higher in snorers than non-snorers even under normal conditions (i.e., no sleep deprivation). Further, the researchers found that even healthy snorers with regular sleep schedules may suffer a chronic sleep debt as a result of their breathing disorder. Tassi et al. (2012) posit that the increased respiratory efforts of snorers during periods of sleep could be responsible for increased daytime sleepiness.

Results from this study suggest the fragility of sleep, because even mild, non-apneic snoring may cause EDS among healthy, young male subjects. With regard to cognitive performance, the researchers found that acute sleep deprivation was more problematic for snorers than non-snorers, leading to lapses in attention and decreased reaction time. Therefore, the authors pose the idea that increased respiratory efforts during the night lead to decreased overall sleep, and eventually to chronic sleep debt.

Effect of Sleep Deprivation on Cognitive Functioning

Working Memory.

According to a recent (2012) study conducted by Lythe, Williams, Anderson, Libti and Mehta, sleep deprivation may lead to impaired cognitive functioning; specifically, the focus of this study was the impact of disordered sleep on working memory tasks. The authors state that, although the neural basis of the impairments following poor sleep is not well understood, changes are most often observed in thalamic activity, and in the frontal and parietal cortices. These cortical areas are implicated in increases and in decreases in task-related activation, and through their research the researchers hoped to pinpoint further cortical areas implicated in attention and working memory, and also affected by sleep deprivation.

For their study, Lythe, Williams, Anderson, Libti and Mehta (2012) examined 20 adult male volunteers with regular sleeping patterns, defined as sleeping 8 plus or minus one hour nightly and no reported daytime sleepiness, as determined by the Karolinska Sleepiness Scale. Subjects underwent brain scans twice, once after a normal night of sleep, and once following 31 hours of sleep deprivation. The researchers administered a parametric verbal working memory task (*n*-back) to assess brain activation following both conditions. Participants were also administered an attention task, which examined both divided and sustained attention.

Results from the study conclude that approximately 31 hours of sleep deprivation alters the normal responsiveness of the brain with increasing working memory demands (Lythe, Williams, Anderson, Libti and Mehta, 2012). Specifically, both the frontal and parietal regions showed attenuated responsiveness following sleep deprivation. Although the results of this study reveal important information about the impact of sleep on working memory, the experimental condition of restricting sleep for a period of 31 hours does not reflect a typical level of sleep deprivation. Many individuals, both children and adults, experience a more moderate level of sleep deprivation, and although it may appear less extreme than 31 hours, it is no less debilitating when considering its chronicity. It would be helpful to understand the effects of a more subtle (though no less harmful) form of sleep deprivation, because it is likely that a greater percentage of patients may be suffering from this type of chronic pattern.

A Belgian study by Stenuit and Kerkhofs (2008) sought to investigate the effects of sleep restriction on cognition in women, in particular. The authors proposed a more modest reduction in sleep as an experimental condition: participants' sleep was limited to

4 hours for three nights, as opposed to a total elimination of sleep. Participants included ten young (20-30 years) and ten aged (55-65 years) women. After a baseline night of sleep (11pm-07am), participants' sleep was reduced to four hours per night for three nights. Following the nights of sleep restriction, the subjects engaged in a recovery night of 8 hours (11pm-07am). Following each condition (baseline night, three nights of sleep restriction, and recovery night), participants were administered neuropsychological tests at various times, focusing on attention (i.e., Trail making test, Stroop-Interference, Tests of Attentional Performance), memory (i.e., Buschke's memory test, Logical Memory, Brown Peterson, PASAT), and addition of numbers and abstraction (i.e., Wisconsin Card Sorting Test). Subjects also were required to complete the Stanford Sleepiness Scale (SSS) every two hours during the sleep-restriction nights.

Stenuit and Kerkhofs (2008) found that, following three consecutive nights of restricted sleep, participants exhibited slower reaction times, although sleep restriction did not seem to affect the accuracy of their responses. The authors note that this slowed reaction time occurred during tasks that were unstructured and not particularly motivating; performance on more complex tasks did not seem to be affected. Further, the researchers found an inhibition of automatic activity (Stroop) and formation of a memory-trace (Buschke's memory test).

Of particular interest to the presently proposed study are the authors' findings on the reaction times of the participants, as well as the difficulty in forming a memory-trace. The authors posit no hypotheses for their findings, simply stating that three consecutive nights of restricted sleep resulted in an overall slowing of cognitive functions, with no modification in the accuracy of their responses. This overall slow-down was

accompanied by what the authors term “a form of impulsiveness (Stenuit and Kerkhofs, 2008).” That is, the participants seemed to have difficulty inhibiting automatic responses as evidenced by performance on the Stroop test (Part C-Interference). It seems that adults, following a few nights of poor sleep, tend to show poor inhibition, memory, and reaction time.

Although these specific tests will not be administered as part of the proposed study, it is interesting to note their findings and to speculate about their generalizability to a pediatric population. The findings of this particular study may help justify the importance of investigating the effects of poor sleep on the same cognitive constructs in children. Further, the proposed study will be conducted on a sample of children with ADHD, a condition often characterized by difficulties with inhibition. If healthy adults without ADHD display decreased inhibition following a few nights of poor sleep, it is logical to wonder about the effects of poor sleep will be on children with ADHD.

Children are understood to be vulnerable to the effects of sleep, both positively and negatively. Therefore, the implications of this study may extend to a child population, who are even more susceptible to cognitive impairments following poor sleep. It has been demonstrated in the adult literature that deprivation often leads to negative behavioral and cognitive consequences; thus, logic denotes that a similar conclusion may be observed in children.

Effects of Sleep Deprivation in Children

Behavior.

Research on sleep deprivation in adults abounds; however, one can recognize the ethical concerns in depriving children of sleep for the purposes of research. Although

such studies would no doubt reveal important information about the significance of sleep in the pediatric population, designing a study to minimize the ethical dilemmas inherent in such research poses quite a challenge. Although empirical evidence in the form of research studies is limited, clinical evidence highlighting the effects of poor sleep on children's functioning is plentiful.

In a review of literature exploring the relationship between sleep and cognitive functioning in a pediatric population, Dahl (1996) writes, individual differences in response to poor sleep are to be expected; however, in general, children who are deprived of sleep tend to exhibit a common pattern of behavior, one that is markedly different from adults who are sleep deprived. Behavior observed among sleep deprived children has included emotional lability, low-threshold for frustration and distress, irritability and difficulties with focused attention. He notes few formal studies focusing solely on the impact of poor sleep on daytime functioning in children, citing instead numerous clinical observations connecting the two. Dahl credits Navalet et al. (1976) for being the first author to report an association between sleepiness and deficits in attention; Navalet et al found a large proportion of adults with narcolepsy reported having attention deficits as children.

Dahl continues his review, citing studies from the realm of obstructive sleep apnea and periodic limb movement disorders linking poor sleep quality to disorders of attention. An elaboration of these studies shall be presented in a subsequent section, although it should be noted that, while his review is relatively brief, he clearly outlines the similarities of the behaviors observed in a sleep-deprived child with those commonly associated with ADHD. He states that, although clinical and observational "evidence" of

cognitive and behavioral impairments as a function of disturbed sleep in children abounds, there is little in the name of scientific data to support the theory that poor attention may be the result of (or may at least be severely impacted by) quality of sleep. Dahl's review is one of several that call for more well-controlled studies to address these issues.

A 2009 study conducted by Paavonen et al. sought to expand upon the theory that the sequelae of disordered sleep in children may manifest as behavioral symptoms rather than overt tiredness. The researchers noted that both hyperactivity/impulsivity and inattention have been noted hallmarks of poor sleep among healthy children by clinicians and parents alike; however, research in this area is scarce. The authors find support for their hypothesis by extrapolating on sleep restriction studies, of which there are few; the experimental sleep restriction studies they cited focused mostly on the impact of sleep deprivation on cognition, although some focused on behavioral aspects as well. Of these, researchers reported a significant increase in inattention scores.

For their study, the team conducted a cross-sectional study of children from Helsinki, Finland, including 146 girls and 134 boys, for a sample size of 280. The children had a mean age of 8.1 years. The researchers used actigraphs to assess sleep quality directly in the subjects, and The Sleep Disturbance Scale for Children and the Attention-Deficit/Hyperactivity Disorder Rating Scale IV were completed by parents. The children were chosen at random from an urban cohort initially comprising 1049 infants born in 1998; a child was deemed eligible if he or she was a healthy singleton born between 35 and 42 weeks of gestation. Children and their parents were invited to be

involved in a follow-up in 2006. Ultimately, the sample size was trimmed to 280 following the implementation of inclusion and exclusion criteria.

The researchers measured quality of sleep with actigraphy; subjects were required to wear the actigraph on their nondominant wrist continually for 7 days. They advised parents to maintain a sleep log, and keep track of bed times, waking times, whenever the monitor was removed, and other issues that may have affected sleep quality (e.g., illness). The Sleep Disturbance Scale for Children was administered to parents, and 6 subscale scores were considered: disorders initiating and maintaining sleep, sleep breathing disorders, disorders of arousal, sleep-wake transition disorders, disorders of excessive somnolence, and sleep hyperhidrosis (Paavonen et al., 2009).

With regard to statistical analysis of the results, the researchers calculated the Pearson's correlation coefficient to examine the connection between troubled sleep and behavioral symptoms. Additionally, the authors conducted a series of multivariate linear regression models to assess their hypothesis that short and troubled sleep is associated with the behavioral symptoms of ADHD specifically. The researchers found that short sleep duration, as measured by actigraphs, and sleeping difficulties, as reported by parents, were independently correlated with an increased presentation of the behavioral symptoms of ADHD (Paavonen et al, 2009).

Quality of sleep will not be measured objectively in the presently proposed study; however, the aforementioned study has demonstrated that parent-report inventories serve as adequate and robust measures of children's sleep quality, and may be sufficient when attempting to diagnose sleep-related behavioral problems. Further, Paavonen et al. (2009) cite additional questionnaire-based correlational studies linking decreased sleep duration

and the behavioral symptoms of ADHD. Thus, the use of actigraph technology, although a means of gathering precise information, is neither necessary nor within the scope of this study.

In continuing the analysis of the behavioral effects of poor sleep in children, Cortese et al. (2005) have concluded via meta-analysis, that children with ADHD exhibit a host of behavioral problems when compared with controls, including more daytime sleepiness, increased movements during sleep, and greater apnea-hypopnea indices. The authors noted, however, that many of the studies that were reviewed failed to control for confounding factors, thus underscoring the importance for future research utilizing both subjective and objective measures.

Neurobehavioral functioning

Attention.

The Continuous Performance Test (CPT) is a neuropsychological measure that is often administered to assess attention, among other variables. The CPT has demonstrated significant differences in attention between children with ADHD and controls, making it an ideal measure to include in this proposed study. Little is understood about the impact of disordered sleep on attention in children with ADHD, although one study conducted in a 2006 study by Gruber et al. demonstrated that sleep moderated vigilance performance on the CPT in a group of children with ADHD, regardless of stimulant use. The authors conclude that, although it has been observed that sleep differences in children with ADHD exist, they remain unsure of the causes or factors underlying those sleep differences.

In 2010, Gruber et al. conducted a study investigating the impact of sleep

restriction on the neurobehavioral functioning of children with ADHD. In this study, children with ADHD were assessed along with a group of control subjects without ADHD in order to assess the impact that sleep deprivation has on Continuous Performance Test (CPT) performance. The authors note that their study stands alone because they were able to manipulate sleep in children in order to examine neurobehavioral performance. They also are among the few studies conducting research on children with ADHD who do not have an absence of breathing problems: much of the literature on children with ADHD and disordered sleep stems from research conducted on children with sleep-disordered breathing (such as obstructive sleep apnea) and restless leg syndrome/periodic leg movement disorder.

With regard to methodology, the researchers monitored sleep using actigraphy, and parents were instructed to keep nightly sleep logs. Subjects wore the computerized wristband-like devices to assess sleep patterns in their natural environments. Actigraphy was deemed a reliable and minimally invasive method of data collection, and was preferable because children were able to remain at home. The researchers used the devices to measure actual time spent asleep, sleep latency, sleep fragmentation, and sleep efficacy. Sleep latency refers to the amount of time taken for child to fall asleep; sleep fragmentation details the extent to which a child's sleep is fragmented, and sleep efficacy refers to the total percentage of sleep minus all periods of wakefulness. The authors assessed sleepiness using the Epworth Sleepiness Scale (ESS), which is an 8-item questionnaire measuring one's likeliness to fall asleep during routine scenarios. Sleep logs included information pertaining to bedtimes and waking times. The CPT is a standardized computer-administered measure of many variables, including attention,

vigilance, and reaction time; this measure was administered to all participants.

The most significant finding was that reducing cumulative reduction in sleep duration by 40.7 minutes was associated with noticeable deteriorations in numerous CPT variables, both in children with ADHD and in healthy controls. The diagnoses of children with ADHD often changed from the subclinical range to the clinical range, as delineated by CPT scores higher than or equal to a T-score of 60. The researchers discovered that children who were sleep deprived were both more inattentive and less responsive to presented stimuli, as evidenced by decreased overall responses on the CPT.

The authors note that the amount of sleep reduction in their study was modest and therefore likely similar to the kinds of sleep deprivation that may occur in daily life; it is not unrealistic that children may experience such mild levels of deprivation on a chronic basis. It seems that even small changes to one's daily schedule, such as minor changes in mealtimes, staying up to do homework or play, may result in compromised neurobehavioral functioning; this is particularly true for sustained attention and vigilance, which are crucial for academic success.

Additionally, the authors stated that, based on their findings and the findings of other studies, "sleep deprivation seems to affect brain circuits that are implicated in the attentional networks that are measured by the CPT (sustained attention and vigilance) (Gruber et al., 2010)." They note that the areas of the brain that form the attentional network require extra sleep to recover, and that the possibility remains that these areas are more vulnerable to sleep deprivation in school-aged children. Their findings continue to be in concert with evidence implicating the "frontal, dorsolateral prefrontal, ventrolateral prefrontal, and lateral temporal and parietal regions are implicated in the

pathophysiology of ADHD (Gruber et al., 2010).”

Working Memory.

Working memory, or the ability to temporarily store, manipulate and organize information for complex cognitive tasks, is critically important for the encoding of new information and knowledge acquisition (Biggs et al., 2011). Working memory is assessed via various modalities, including the digit span (DS) subtest of the Weschler Intelligence Scale for Children, Fourth Edition (WISC-IV). This task is comprised of two separate sub-tasks, the digits forward (DF) and digits backward (DB); the scores obtained on these sub-tasks yield separate raw scores, but are combined to obtain one total scaled score. It has been theorized that the DF and DB sub-tasks, although both are part of one single score, they are actually distinctly different, yielding information about separate constructs (Rosenthal, Riccio, Gsanger & Jarratt, 2005).

Rosenthal et al. (2005) posit the idea that the memory processes involved in a forward-recall task differ significantly from those involved in a backward-recall task; specifically, the DF task measures short-term auditory memory, simple verbal expression and sequencing, whereas the DB task is more sensitive to working memory deficits. For the purposes of the proposed study, both the DF and the DB sub-tasks will be investigated, because the argument about their differences is outside the scope of this project. Both are part of the larger DS total score, and both are used to assess the construct of working memory.

A 2011 study by Calhoun et al. aimed to assess the impact of excessive daytime sleepiness on the cognition and behavior of young children. The authors state that their study is among the first to present the relationship between excessive daytime sleepiness

and parent-reported learning, conduct problems, attention/hyperactivity, and neurocognitive functioning.

The researchers used a final sample of 508 children, ranging from kindergarten through fifth grade. Of note, the authors did not exclude children diagnosed with medical problems (36.0% allergies, 13.3% asthma and 1.2% juvenile diabetes), mental health disorders (11.0% ADHD, 1.7% depression/anxiety, 0.8% autism), or a learning disability (9.1%), so that the sample population would be representative of the general population. All subjects underwent both objective and subjective assessments; a medical assessment as well as parent-completed questionnaires were completed for each subject. Each subject was then evaluated for one night in sound-attenuated and temperature-controlled rooms for a period of 9 hours. The researchers used electroencephalogram, electrooculogram, as well as chin and bilateral electromyogram to record data. Respiration, nasal pressure, hemoglobin oxygen saturation, snoring sounds, and thoracic and abdominal strain gauges were also monitored.

All parents completed the Pediatric Sleep Questionnaire in order to provide information regarding excessive daytime sleepiness, the focus of the study. Parents were also administered the Pediatric Behavior Scale, to assess behavior, learning problems, and ADHD.

Children underwent a 2.5 hour neurocognitive evaluation prior to their stay in the sleep laboratory; the researchers chose measures specifically to assess intelligence, attention, executive functioning, memory, visual-motor skills, and processing speed.

The authors found that excessive daytime sleepiness in young children was

associated with increased parent-reported learning, attention/hyperactivity, and conduct problems (Calhoun et al., 2012). Calhoun et al. (2012) note that daytime sleepiness is associated with impairments in children's ability to pay attention in school, as well as overactivity during the day. Therefore, excessive daytime sleepiness may make learning more difficult for children who suffer from this, chronically; indeed, the authors reported that 57% of parents involved in the study stated that their child had problems learning, suggesting that as the child becomes more sleep-deprived, the risk for learning difficulties, low grades, trouble with reading, writing and arithmetic, and incomplete and disorganized school work increases commensurately. Finally, Calhoun et al. (2012) reported another interesting finding: processing speed may be the key mechanism which influences both attention and learning outcomes, since the connection between daytime sleepiness and attention and learning problems was mediated by processing speed. That is, being sleepy may slow down thought processes or one's ability to process information in a quick, efficient manner, leading to lower alertness and concentration. Working memory also affected learning and attention outcomes, and although in this study the effect was slightly smaller when compared with the impact of processing speed on the constructs, the effects were still significant. Thus, excessive daytime sleepiness appears to affect numerous neuropsychological constructs associated with learning and school performance, including attention, working memory and processing speed.

Reaction Time.

Although the focus of the proposed study is on attention and working memory, reaction time is another area of interest, and one that may be negatively impacted by poor sleep. Building on Stenuit & Kerkhofs' study (2008), which demonstrated decreased

reaction times in adults following a period of restricted sleep, a part of the proposed study will be devoted to the impact of disturbed sleep on this construct in children.

Lecendreux, Konofal, Bouvard, Falissard & Mouren-Simeoni (2000) evaluated alertness in children with ADHD, using polysomnography. Thirty boys with ADHD (aged 5 to 10 years) and 22 age and gender-matched controls were evaluated as part of this study. Children were administered the Multiple Sleep Latency Test and reaction time tests during the day.

The researchers found that no significant differences in sleep variables emerged between the boys with ADHD and controls; however, the latency period was shorter in the boys with ADHD. Also, of some interest, the mean reaction time was longer among the subjects with ADHD. Specifically, the researchers found that the reaction times for children with ADHD were 1.4 times higher than in controls; while the ADHD-group's performance was more heterogeneous (results spanning poor to very good). The children with ADHD not only exhibited longer response times, but there were also more observed errors in omission and commission. Children with ADHD were observed to tire more quickly and were more inattentive than controls, and were noted to be easily distracted and impulsive. The authors noted also that the subjects with ADHD were sleepier during the day than were controls; subjects with ADHD were observed to perform more poorly than controls among all tests administered.

Overall, the researchers found that children with ADHD had an "abnormally strong tendency to fall asleep during the day"(Lecendreux et al., 2000). The authors concluded that children with ADHD present with a deficit in alertness, which is hypothesized to be related in some way to sleep difficulties.

Summary

It seems that chronic sleep deprivation in children is especially deleterious, and may be impacting functioning across several domains. School success is fairly reliant on one's ability to sustain attention and multi-task, two skills which appear to be diminished among children with sleep disorders and also among children with attentional disorders. Research has demonstrated that children with sleep disturbances exhibit a wide variety of deficits in neuropsychological functioning, including reduced working memory and attention, and increased reaction time.

Attention, working memory and reaction time are three specific areas which appear to be sensitive to the effects of poor sleep hygiene or sleep deficits, and are of particular relevance to the proposed study. With regard to effects on attention, researchers have demonstrated that even moderate sleep deficits are associated with diminished performance on the CPT-II, in children with and without ADHD (Gruber et al., 2010). The construct of working memory has also been investigated as it relates to poor sleep; Calhoun et al. (2012) found that excessive daytime sleepiness, likely the result of poor sleep during the night, was associated with diminished learning and school performance. More specifically, attention, working memory and processing speed were particularly affected. Reaction time has also been evaluated as it relates to sleep quality, and researchers have found that children with ADHD tended to be sleepier during the day, and exhibited longer reaction times when compared with a non-clinical sample. They also made more omission and commission errors.

Therefore, it appears that the quality of one's sleep affects many areas of functioning; although the present study aims to examine only three of these areas

(attention, working memory and reaction time), the studies mentioned imply the significance that sleep holds on all areas of functioning. Parents, teachers and caregivers alike would probably benefit from the knowledge that good-quality sleep is not only important for overall health, but also for success in school and beyond.

CHAPTER 3

Hypotheses

Hypothesis 1.

Among two groups of children evaluated at an outpatient mental health clinic located on the east coast, the group of children with sleep disorders will have a higher prevalence rate of ADHD than those without sleep disturbances.

Hypothesis 2.

Children with sleep disturbances are more likely to perform in the clinical range on the Continuous Performance Task-Second Edition (CPT-II); specifically, children with sleep disturbances are expected to make more errors of commission and omission, as well as exhibit decreased reaction time.

Hypothesis 3.

Children with sleep disturbances are likely to perform below the average range on the Digit Span forward and Digit Span backward subtests of the Weschler Intelligence Scale for Children-Fourth Edition (WISC-IV), which taps into working memory abilities.

CHAPTER 4

Method

Overview.

The proposed study used quantitative methodology to examine hypotheses related to sleep disturbances and performance on neuropsychological measures among school-aged children. Specifically, it was hypothesized that children with sleep disturbances (per scores on CSHQ) will exhibit scores in the clinical range on the Continuous Performance Task (CPT-II); performance on the Digit Span forward and backward subtests of the WISC-IV is hypothesized to be lower as compared to non-sleep disordered peers.

Design and Design Justification.

The proposed study used quantitative, correlational analyses to determine the presence of a relationship between sleep disturbances and performance on neuropsychological measures. The data were derived from a previously collected archival data set; this existing data set was easily accessible, and the role of sleep on neuropsychological functioning is of particular interest to the clinicians who are involved in administering neuropsychological evaluations.

Participants.

Participants included patients seen for a neuropsychological evaluation at a hospital-based outpatient facility specializing in pediatric psychological and psychiatric services located in a large metropolitan area on the East Coast. Thirty were male, 24 were female. At the time of testing, 26 participants were taking at least one medication. Forty subjects were Caucasian; 5 were Asian/Pacific Islander, 3 unspecified, 1 African

American and 1 Latino. Additionally, 36 subjects received a diagnosis of ADHD; 18 received another diagnosis. Of the 36 subjects with ADHD, 25 met the criteria for sleep disturbances (scores of at least one standard deviation below the mean); of the subjects receiving other diagnoses, 11 met the criteria for sleep disturbances.

Inclusion Criteria.

Participants were between the ages of 6 and 10, and were brought in for a neuropsychological evaluation to assess for difficulties with attention and/or school performance. Participants needed to complete all forms in their entirety to be included in this study.

Measures

Children's Sleep Habits Questionnaire.

The Children's Sleep Habits Questionnaire (CSHQ) was administered to all parents of subjects. The CSHQ was chosen for this study because it is one of the few measures intended for evaluating the sleep habits of children, and is relatively easy to administer and score. The CSHQ is a parent-report survey of sleep behaviors among school-aged children; it is comprised of items relating to various critical sleep domains and encompasses the most prevalent sleep complaints of children aged 4 through 10. Specifically, the CSHQ poses questions about sleep onset delay, bedtime resistance, anxiety around sleep, sleep duration, night wakings, parasomnias, sleep disordered breathing, and morning waking/daytime sleepiness. Parents are asked to provide information about sleep behaviors as they typically occur during the week. Items are then "rated on a three-point scale: "usually" if the sleep behavior occurred five to seven times

/week; “sometimes” for two to four times/week; and “rarely” for zero to one time/week (Owens, Spirito, and McGuinn, 2000).”

The CSHQ was evaluated on a community sample of 469 children aged 4 to 10, and a clinical sample of 154 patients diagnosed with a parasomnia, sleep-disordered breathing, or behavioral sleep disorder in a pediatric sleep disorders clinic. Internal consistency was determined to be 0.68 for the community sample, and 0.78 for the clinical sample. Pearson’s correlations for the subscales ranged from 0.62 to 0.79, which are acceptable levels. Validity was assessed by comparing data from the clinical sample with data from the community sample for each of the items and subscales of the CSHQ. The clinical group had higher (worse) scores than the community sample on all items, with one exception (wakes by self, item 38). The majority of the items proved statistically significant; thus, the measure is valid in its ability to consistently differentiate the community group from the clinical group.

Connors’ Continuous Performance Task-II.

The Connors’ Continuous Performance Task-II (CPT-II) was chosen for its wide usage as an integral component of neuropsychological evaluations, specifically for its ability to assess attention, concentration, and impulsivity. For the purposes of the proposed study, the scores from the omission, commission and reaction time were utilized to assess these variables. The omission score reveals the number of times the subject failed to respond to the target letters (i.e., non-X letters). Commission scores determine how many times the subject responded to non-targets (i.e., X). The hit reaction time overall (Hit RT) score is the average speed of correct responses across the entire test.

The CPT-II is scored entirely by computer, and the examiner is provided with the scores for each subject. An ADHD Confidence Index is then provided based on the scores; the subject's scores are compared with clinical and non clinical profiles. For the purposes of this study, because the scores are not being considered as part of a whole but rather in isolation as indicators of inattention or decreased reaction time, the researcher will be examining the T-scores of the three measures of interest. T-scores above 60 will be considered "high;" high scores in omission, commission and Hit RT are considered indicators of inattentiveness and decreased reaction time.

Wechsler Intelligence Scale for Children-Fourth Edition.

The Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV) is the most recent edition of the Wechsler scales, and may be administered to children between the ages of 6 and 16. This test consists of 15 subtests (10 core and 5 supplemental) that combine to form four different composite scores: Verbal Comprehension, Working Memory, Perceptual Reasoning, and Processing Speed.

The WISC-IV was standardized on 2,200 children selected to represent the United States. The standardization group consisted of children ranged in age from 6 to 16, and included the following ethnic groups: Euro American, African American, Asian American, Hispanic American, and Other. Children were sampled from all four geographical regions of the United States (Northeast, South, Midwest and West).

The WISC-IV is generally considered to have excellent reliability: internal consistency reliability coefficients range from .91 to .95 for the Verbal Comprehension measures, from .91 to .93 for Perceptual Reasoning, from .90 to .93 for Working Memory, from .81 to .90 for Processing Speed and from .96 to .97 for the Full Scale.

Of particular interest to the proposed study is the Digit Span subtest, which is part of the Working Memory composite. Scores from this subtest were examined in isolation; that is, the composite score for the Working Memory tasks were not evaluated as a whole for the purposes of this study. With regard to the reliability and validity of this particular subtest, internal consistency reliability ranges from .81 to .92.

Procedure

The data used for the purposes of this study were archival. Each subject was administered the CPT-II and WISC-IV as part of a neuropsychological evaluation, and the CSHQ was given to parents. The hard copies of the administered forms were reviewed, scored, and entered by the researcher into a new de-identified data set. The CSHQ was used to form two groups based on scores (those with and those without sleep disorders). The CPT-II data for the variables of omission, commission and reaction time were recorded and T-scores above 60 for the three measures of interest were considered indicators of inattention and decreased reaction time. The researcher also recorded whether, after formal evaluation, a child was diagnosed with ADHD. After scores were entered, the forms were returned to their files within the clinic. All data were maintained and analyzed using SPSS.

CHAPTER 5

Results

The first hypothesis states that, among two groups of children evaluated (those with sleep disorders and those without), the group of children with sleep disturbances will have higher instances of ADHD diagnoses. As this is a comparison between two groups using a categorical variable, a chi square test was used to determine the extent to which the two variables were related. The Pearson Chi-Square value ($X^2(1) .375, p > .05$) indicated that there were no significant differences in levels of ADHD for those with and without disturbed sleep.

The second hypothesis states that children with sleep disturbances are more likely to perform in the clinical range on the Continuous Performance Task-Second Edition (CPT-II); specifically, children with sleep disturbances are expected to make more errors of commission and omission, as well as exhibit decreased reaction time. To investigate whether the presence of sleep disturbances predicted performance on the CPT-II's three subscales, three linear regressions were computed. Sleep disturbances did not predict omission errors, $F = .296, p > .05$, adjusted R square = $-.013$. This indicates that 1.3% of the variance for omission errors was explained by the presence of sleep disturbances. Sleep disturbances were also not predictive of reaction time, $F = .345, p > .05$, adjusted R square = $-.013$, nor errors of commission, $F = .518, p > .05$, adjusted R square = $-.009$. Reference Table 1 for the mean, standard deviation, range and clinical cut-off information.

Table 1

Subscale Data Information

	Mean	Standard Deviation	Range	Clinical Cut-off
CPT-II Reaction Time__	46.30	17.66	81.13	T=60
CPT-II Omission	52.25	17.05	97.39	T=60
CPT-II Commission	52.12	15.92	76.19	T=60
WISC-IV DSF	7.93	4.77	0-16	
WISC-IV DSB	8.09	4.91	0-17	

The third hypothesis states that children with sleep disturbances are likely to perform poorly on the Digit Span Backwards and Forwards subtests of the Weschler Intelligence Scale for Children-Fourth Edition (WISC-IV). To investigate whether sleep disturbances predicted performance on the Digit Span (forward and backward) subtests of the WISC-IV, two linear regressions were computed. Reference Table1 for mean, standard deviation, and range information for both tasks. Sleep disturbances did not predict the Digit Span forward, $F=1.021$, $p>.05$, adjusted R square= .000 nor did sleep disturbances predict Digit Span backward, $F=.115$, $p>.05$, adjusted R square= -.017.

Discussion

Gruber (2010) noted that sleep problems commonly associated with ADHD in children include frequent night awakening, bedtime resistance, restless sleep, decreased sleep duration, difficulty waking up in the morning, high levels of nocturnal activity, and unstable/inconsistent sleep patterns. As several of these domains were assessed by the CSHQ, and previous studies have demonstrated the association between sleep

disturbances and cognitive functioning, it was anticipated that results would mirror the existing literature. The first hypothesis proposed that, among two groups of children (those with and without disturbed sleep), rates of ADHD would be higher in the group of children with sleep disturbances. Results indicated that there were no significant differences in levels of ADHD for those with and without sleep disturbances. Although these results are different than anticipated, it should be noted that this sample consisted of children who were being evaluated in a clinic for neurodevelopmental disorders. The literature indicates that approximately 75%-80% of children with complex neurodevelopmental disabilities also have sleep problems (Beebe, 2012). Perhaps the children were not able to truly be differentiated by sleep disturbances, as the majority of them reported difficulties with sleep. Therefore, ADHD was not a differentiating variable because there was not enough variability among subjects on levels of sleep disturbances.

According to the statistical analyses conducted in the present study to address the second and third hypotheses, the presence of sleep disturbances in children diagnosed with ADHD is not predictive of performance on the CPT-II or the Digit Span (forward, backward) subtests of the WISC-IV in the sample studied. Again, these findings seem to contradict current literature.. While numerous studies have correlated sleep problems with performance on cognitive tasks as well as behavioral functioning (Lythe, Williams, Anderson, Libti and Mehta, 2012; Calhoun et al., 2012; Calhoun et al., 2011; Gruber et al., 2010; Cortese et al., 2005; Lecendreux, Konofal, Bouvard, Falissard & Mouren-Simeoni, 2000), the existing literature on sleep in children fails to differentiate between behaviors that are affected by ADHD alone, and those affected by poor sleep; it is

difficult to differentiate which symptoms occur as a result of ADHD, and which result from disturbances in sleep.

Another issue to consider when interpreting the results is that the CSHQ has no specific cut-off for determining whether a child has a sleep disorder; for the purposes of this study, scores that were greater than one standard deviation below the mean were considered an indication of sleep disturbances. Since this measure was used to separate the children into two groups (i.e., those with sleep disturbances and those without) they may not have been grouped accurately; it is possible that all scores were within the clinical range or were within normal limits. As such, the CSHQ may not have been the ideal tool to measure sleep, as there are no precise clinical cut-offs to use as an indicator of a clinically significant problem versus normal sleep patterns.

Children with ADHD often struggle with measures of attention, working memory and reaction time, regardless of the presence of disturbed sleep. Perhaps a reason why sleep did not predict performance on these measures is that these measures are typically used to diagnosis children with ADHD. Therefore, since all children in this analysis were diagnosed with ADHD, sleep may have not been a contributing factor to any deficits displayed during task performance. It should be noted, however, that not all children with ADHD perform poorly on these measures, and that performance on office-based tasks is simply one of the factors considered when making a determination of the presence of ADHD; significant behavioral issues must also be present (sleep disturbances, etc.). Thus, the simple statement that many children with ADHD struggle on measures of attention, working memory, and reaction regardless of sleep may be too simplistic an explanation because there were other factors present that were not accounted for in the

current analysis The presence of impairment on measures of attention, working memory, and/or reaction time may be due to several factors, including ADHD (or other psychiatric diagnoses), medication use, poor sleep and any number of other factors not considered to be within the scope of the current study. As such, any one or combination of these factors may have affected the subjects' performance on the neuropsychological measures employed in the current study, making it difficult to determine the etiology of the cognitive impairment. Since poor sleep was prevalent across both ADHD and non-ADHD groups, it is likely that sleep is contributing in some way; however poor sleep being the causal factor in the subjects' performances may not definitively be made as several potential contributory variables were not controlled for during data analysis.

In addition, the measures that were utilized for the current study may not have been ideal to assess the effects of poor sleep in children with ADHD, as children with ADHD tend to exhibit an overlap of symptoms of poor sleep and inattention. It may also be the case that the single tests that were used as measures of working memory (specifically, Digit Span forward and backward) were simply too narrow in scope, meaning that perhaps other factors of working memory that were not assessed via the Digit Span scores may have been present in the other measure of working memory on the WISC-IV (i.e., the Letter-Number Sequencing task); thus, it is possible that the full Working Memory Index from the WISC-V may have yielded more sensitive results by encompassing more aspects of working memory. Specifically, while the Digit Span subtests measure working memory and attention, the Letter-Number Sequencing task assesses processing speed and sequencing abilities (in addition to attention span); the

addition of this task to the present analysis may have yielded different results by providing a more complete assessment of working memory abilities.

Another potential explanation for the apparent lack of association between the variables of interest could be due to the nature of the parent report questionnaire (CSHQ). It is possible that the parents may not be accurately describing their child's sleep patterns, and may be over-or-under reporting behavior. Self-report (and parent-report) questionnaires are bound to be less sensitive and more prone to inaccuracies than objective measurements, such as actigraphy, as they are subjective rather than objective measurements of behavior. This is not meant to imply that they are not useful, it is merely to posit the idea that questionnaires are subject to biases that may make them less accurate than objective measures. Additionally, parents may not be fully aware of a child's sleep patterns and behaviors that occur during the night when they themselves may be asleep. It is worth stating, however, that the CSHQ is one of the only measures in use which aims to target the sleeping patterns/behavior of children; there is a marked paucity of sensitive and reliable sleep measurements for this population. There will likely always be issues of accuracy when someone else other than the subject (i.e., a parent) reports on behavior; this should be considered by clinicians when working with children who are unable to fill out their own questionnaires.

Limitations

There are several limitations to the current study. One such limitation is the fact that there are no precise cut-off levels in the CSHQ which state definitively that a child has a sleep disorder; rather, for the purposes of examining the data in the current study, a cut-off of one standard deviation below the mean was imposed as a way of determining

the presence of disordered sleep. It could be that the children in the present study did not actually have a sleep disorder, despite endorsing an increased number of clinical symptoms on the CSHQ.

In addition, the sample used in the present study was small and economically homogenous (affluent), which may not represent the general population. Higher socioeconomic status could have implications for both assessment and treatment, as these families are more likely to have access to services and treatments that may not be widely available. Parents who are more educated and savvy to the presence of problematic cognitive and/or academic behavior may be more likely to seek a comprehensive neuropsychological evaluation.

Additionally, the current study did not consider the impact that psychiatric medications may have on children's sleep. Some of the children in the clinical sample were taking psychiatric medications at the time of the evaluation, while others were not; a common side-effect of stimulant medications often used to manage the behavioral symptoms of ADHD may result in sleep problems (Owens, 2009). All children were included in the study, regardless of medication use, because excluding a large number of children who were medicated would reduce the practical applicability of the results. That is, many children were using medications to help control mood and behavior symptoms, and excluding these children from the study would mean that the results only apply to children not using medication. In a clinical sample where the vast majority of children meet criteria for at least one psychiatric diagnosis and often are prescribed medication, this would drastically reduce the generalizability of the outcomes. Further, given that the

medications may affect sleep, this may account for the high level of sleep disturbances overall in this sample.

Future Directions

Future research studies may focus on the specific domains of sleep as assessed by the CSHQ, and examine whether specific sleep behavior or patterns are related in any way to behavioral, emotional or cognitive functioning. For example, it may be the case that children who have trouble falling and/or staying asleep have more emotional, cognitive or behavioral difficulties; it would be useful to know what or if certain sleep behaviors are associated with cognitive and/or functional difficulties, to begin setting goals for treatment. To measure this, behavior questionnaires that assess real-life behavior may be preferable to measures obtained in an office-setting; Beebe (2012) writes that “office-based tests of academic knowledge appear to be less sensitive than measures of actual classroom performance, suggesting the presence of functional deficits that may be “controlled away” during highly structured standardized testing, analogous to what has been described for the measurement of attention and executive functioning.”

Studies may also expand the analyses to include behavior measures which are also used to make a diagnosis of ADHD; an interesting relationship may exist between the CSHQ and other parent or teacher rating scales. It would be important clinically to note the presence of a relationship between poor sleep and problematic behavior; if sleep is suspected as a contributing factor to a patient’s functional difficulties, again it would be important to make sleep a focus of treatment. A future study may provide the CSHQ in addition to parent, teacher and self-rating scales (age-appropriate) prior to initiating sleep interventions (sleep training, sleep hygiene, etc.) and then again following the

intervention to observe the effects of remedying problematic sleep behaviors on overall functioning. It is possible that poor sleep in children may be related more robustly to behavior than cognition; parents, educators and clinicians alike would benefit from attending to sleep as a contributing factor in one's overall level of functioning.

Understanding not only the prevalence but the impact of sleep disturbances can aid clinicians when formulating treatment plans, and in making appropriate referrals when necessary. For instance, upon reviewing a child's CSHQ, a clinician may understand that a child is having greater difficulty sleeping, and could prioritize sleep hygiene as a goal for intervention. While the present study did not show an association between the presence of sleep disorders and cognitive functioning, numerous other studies have demonstrated this relationship (Lythe, Williams, Anderson, Libti and Mehta, 2012; Gruber et al., 2010; Dahl, 1996). If sleep is suspected as a factor in a child's overall level of functioning, the child may be referred for sleep hygiene training, or a sleep study to determine the precise nature and extent of the problem.

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