I Don't Want To Go To Bed Yet: Sleep Deprivation in School-Aged Children

Fiona Davidson

Mount Saint Vincent University

Committee members: Dr. Penny Corkum (Supervisor) and Dr. Jennifer McLaren

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Abstract

Sleep is an important component of child development, yet a growing number of children are sleeping fewer hours than recommended. Correlational research has showed a significant relationship between shortened sleep and difficulties with academic performance, attention and behaviour, however, very few studies experimentally manipulate children's sleep to evaluate the daytime consequences. This study examined the impact of sleep restriction on attention, behaviour, and cognitive functioning in typically developing children. Sleep duration was restricted and extended by one hour in relation to baseline sleep for 4 nights each. The impact of these sleep conditions was assessed through both objective (one-to-one tests) and subjective (parent, teacher, RA, child questionnaires) measures. We hypothesized that all informants would report a decrease in behavioural functioning (e.g., increased opposition, impulsivity and hyperactivity) in the sleep restricted condition compared to sleep extended condition, and that children would perform less well on tasks of academic functioning during the sleep restriction condition. Results showed significant differences on parent ratings of attention and behaviour in the restricted versus extended sleep condition. Teachers and children did not report any significant changes. Importantly, the research assistant was blind to experimental condition, and reported significant changes. Significant differences were also found on tasks of short-term memory. These results indicate that even modest amounts of sleep restriction can affect daytime behaviour in children, however, the changes may be subtle and not observable in a classroom context.

I don't want to go to bed yet: Sleep deprivation in school-aged children

Although sleep is important for healthy development in elementary school-aged children, sleep problems are very common, affecting approximately 20-30% of children (Tikotzky & Sadeh, 2001). The most commonly parent-reported sleep problems in children are bedtime resistance, difficulty falling asleep, night awakenings and shortened sleep duration (Moore, Meltzer, & Mindell, 2007). Past research studies have indicated that sleep difficulties in children are correlated with negative outcomes, however, causal links are still unknown (Sadeh, 2007). To further examine this relationship, the current study was focused on the impact of mild cumulative sleep restriction on daytime functioning in typically developing, school-aged children.

In addition to the sleep problems that affect many children, children without such difficulties are generally getting less sleep now than they have in the past (Iglowstein, Jenni, Molinari, &Largo, 2003). A survey by the National Sleep Foundation (US) was focused on sleep in children and revealed that school-aged children need on average 10-11 hours (600 min-660 min) of sleep per night. However, the mean number of hours that children were sleeping was 9.4 hours (564 minutes) (National Sleep Foundation, 2004). Many factors contribute to sleep problems and short sleep duration in children, such as: child factors (e.g., co-morbid mental health/psychiatric disorders, temperament); family variables (e.g., parent knowledge of good sleep hygiene, parental mental health, family composition, family work and school schedules); and environmental factors (e.g., child's bed/bedroom, access to television/computer) (Owens, 2007). In a review of sleep and sleep disorders in childhood, Meltzer and Mindell (2006) reported that the most common cause of daytime sleepiness in children is insufficient sleep duration and not primary sleep problems such as narcolepsy or sleep-disordered breathing. In

school-aged children, shorter sleep duration appears to be most often related to increasingly later bedtimes (Owens, 2007).

Research on pediatric sleep has become more common over the last two decades (Mindell, et al., 2011), and the findings have important implications for children with diagnosed sleep disorders, as well as for children with no direct evidence of sleep disorders, but who may sleep less than required. Sleep in children is especially important for optimal daytime functioning. Students who have shortened sleep duration may be negatively affected in terms of their performance at school and may experience academic failure (Buckhalt, Wolfson, & El-Sheikh, 2009). This may be due to daytime sleepiness, which ultimately can lead to decreased ability to attend to details and concentrate on schoolwork, as well as reduced ability to learn and retain new information (Meijer & van den Wittenboer, 2004; Curcio, Ferrara, & De Gennaro, 2006). The academic outcomes that have been negatively affected by decreased sleep duration and variable sleep schedules include: teacher ratings, academic grades, as well as performance on achievement tests, test of neurocognitive functioning, and norm-referenced intelligence tests (Buckhalt, Wolfson, & El-Sheikh, 2009). Children with sleep problems are also more likely to have school attendance problems, which in turn can exacerbate academic problems (Carvalho Bos et al. 2009). In addition to the negative impact of reduced sleep duration on schoolwork, Meijer & van den Wittenboer (2004) found that sleep quality also indirectly affected cognitive performance.

Children with sleep problems not only have poorer daytime functioning, but are also more likely than their typically developing peers to suffer from mental health problems, such as emotional and behavioural difficulties (Ivanenko et al., 2004). For example, sleep problems have been found to be commonly associated with anxiety disorders and affective disorders in children

(Sadeh et al., 1995). Attention-Deficit/Hyperactivity Disorder (ADHD) is a highly prevalent mental health disorder which affects approximately 5-10 % of school-aged children (APA, 2000) and has been associated with sleep problems, including difficulty falling asleep, staying asleep and frequent night awakenings (Corkum, Moldofsky, Hogg-Johnson, Humphries, & Tannock, 1998; Owens, 2005). In fact, sleep difficulties were previously included in the diagnostic criteria for ADHD in the DSM-III. The prevalence of sleep problems in children with ADHD has been estimated to be between 50 and 95% (Corkum et al., 1998; Owens, 2005). Given that sleep affects attention and behaviour, and difficulties with attention and behaviour characterize ADHD, it is not surprising that the literature suggests a link between sleep and ADHD (Corkum et al., 1998; Owens, 2005).

Storch et al. (2008) found that sleep problems were positively correlated to the severity of mental health problems in both children and adolescents. Additionally Coulombe, Reid, Boyle, & Racine (2010) examined the relationship between sleep problems and psychopathology based on parent and teacher ratings. Although they were not able to determine the directionality of the relationship, their findings indicated that insufficient sleep is correlated with the presence of psychopathologies in children**.**

In summary, most of the existing research, as reviewed by Buckhalt, Wolfson, and El Sheikh (2009), involved simple or multiple correlations and showed that poor sleep in children is associated with deficits in academic achievement and cognitive functioning (e.g., working memory, executive functioning, and attention), increased behavioural problems, difficult temperament, increased negative mood, and poor emotional regulation (Sadeh, 2007). Although the evidence would indicate that reduced sleep is related to poorer daytime functioning in

children, causal links cannot be assumed based on these correlations and results should be interpreted with caution.

The daytime consequences of insufficient sleep in adults have been well documented. A review by Durmer and Dinges (2005) found that reduced sleep duration sleep resulted in deficits in mood, cognition, and motor performance, even when individuals reported an absence of daytime sleepiness. Interestingly, the researchers found that executive functions (such as attention) were particularly vulnerable to sleep deprivation. These findings were consistent with findings from an earlier meta-analysis by Pilcher and Huffcutt (1996), whereby mood, cognition and motor performance were negatively affected by sleep deprivation. Moreover, Pilcher and Huffcutt (1996) found that chronic partial sleep deprivation had a greater impact on daytime functioning than acute total sleep deprivation.

Although the daytime consequences of sleep deprivation in adults have received much research attention, the same area of research for the pediatric population is limited (Sadeh, 2007). There have been only six empirical studies published that have used experimental research designs to assess the causal relations between sleep restriction and daytime functioning in children (Carskadon et al., 1981a & 1981b; Fallone et al., 2001 & 2005; Randazzo et al., 1998; Sadeh et al., 2003). Of these six studies, three had within-subjects designs and three had between subjects designs. Two of the within-subjects studies were completed by Carskadon et al. (1981a, 1981b). In one study the effect of a full night of sleep deprivation was examined (Carskadon et al., 1981a). In the second study, (Carskadon et al., 1981b), sleep, performance, and sleepiness were examined after sleep restriction of only 4 hours in bed. The third study that had a within-subjects design was by Fallone et al. (2005), who conducted a home-based study where participants followed one of three sleep schedules (typical school-night schedule, optimized

schedule, and restricted schedule). Based on teacher reports, it was found that insufficient sleep increased ratings of attention problems and increased academic problems relative to baseline conditions.

The three sleep experimental sleep manipulation studies that had between-subjects designs were Randazzo et al. (1998), Fallone et al. (2001), and Sadeh et al. (2003). Randazzo et al. (1998) compared cognitive performance between two groups; one control group, and one sleep restricted group (one night of restriction, where participants were allowed 5 hours in bed). Results revealed that cognitive performance was negatively affected in the group with reduced sleep duration in comparison to the control group. Fallone et al. (2001) examined the impact of sleep deprivation in school-aged participants, where one group was sleep restricted (only 4 hours in bed), and the other group had optimized sleep (10 hours in bed). Results indicated that performance was not decreased on response inhibition or sustained attention tasks in the sleep restricted group. Sadeh et al. (2003) examined the effects of sleep manipulations on children by assigning children to one of three groups: a sleep extension group, a sleep restriction group, and a no-change group (children who were not able to manipulate their sleep by 30 minutes or more). Significant interactions were found on tasks of cognitive functioning and results showed that children in the sleep restricted group showed no change in their performance on some variables, whereas the children in the sleep extended group showed improved performance from baseline to post-intervention.

Of the six sleep manipulation studies, the amount of sleep restriction varied between one night of total sleep deprivation, a few hours for one night (acute sleep restriction), and an accumulation of hours over the course of three to six nights. The four studies examining total sleep deprivation or acute sleep restriction (Carskadon et al, 1981a & 1981b; Fallone et al 2001;

Randazzo et al. 1998) showed that experimentally manipulating children's sleep negatively impacted their performance on tasks demanding higher cognitive abilities, such as executive functioning. Fallone et al. (2005) and Sadeh et al. (2003) examined the impact of reducing children's sleep over a longer period of time, one to three hours per night for less than one week. Their findings were that the reduction in sleep had a negative impact on attention, memory, and processing speed, based on teacher report. These studies suggest that even a very moderate amount of sleep restriction (e.g., one hour over a few days) can significantly affect higher cognitive functioning (Sadeh et al., 2003).

The studies described above revealed conflicting results, which may in part be related to varying research designs (e.g., between- versus within-subjects designs, total sleep deprivation versus sleep restriction, acute versus chronic sleep restriction). In addition to limited research available on sleep deprivation in children, much of the research that does exist was conducted within the same research laboratory. A strength of the current study was that there were multiple informers who rated the children on their ADHD symptoms, and behavioural functioning. This provided information on the children in the academic setting, the home setting, as well as in a one-on-one setting directly following four nights of sleep restriction. Additionally, both teachers and research assistants were blind to experimental condition. Only one previous study examined teacher reports of children during an experimental sleep manipulation (Fallone et al., 2005), and none of the previous experimental manipulation studies included a research assistant rating. Given the high rates of sleep problems and the potential negative impact on children's development, further experimental research is needed.

The current study was conducted in order to build on the existing research by examining the effects of restricting versus extending sleep on daytime functioning (attentional, behavioural

and cognitive) in typically developing children. Moreover, the study will be one of a few studies that will directly examine the causal relationships between sleep and daytime functioning. Our results will help us to understand the impact of shorten sleep duration in children and in particular will speak to the potential relationship between sleep and ADHD symptoms.

The current study was an experimental, within-subjects design, therefore, each participant experienced, and was tested in each of the two sleep conditions, and the differences among individuals was measured and separated from error. Sleep duration was restricted and extended by one hour in relation to baseline length of sleep. The impact of these sleep conditions was assessed through both objective (one-to-one administered tests) and subjective measures (parent, teacher, research assistant, and child reports). ADHD symptomatology and behavioural functioning were examined by comparing parent, teacher, research assistant, and child reports from each condition (extended sleep versus restricted sleep). Each participant's cognitive functioning was examined by tests delivered one-on-one in the laboratory following each sleep condition. The current study was part of a larger study that focused on examining the impact of sleep deprivation on emotional and attentional regulation in typically developing children.

The hypotheses for the current study were:

1) Parents, teachers, research assistants, and children will report a decrease in behavioural functioning (e.g., increase in oppositional behaviour), and an increase in ADHD symptomatology (e.g., increase in hyperactivity/impulsivity and inattention) in the sleep restricted condition when compared to the sleep extended condition, indicating that less sleep is detrimental for attention and behaviour during the day.

2) Children will perform more poorly during their sleep restriction week, as compared to their sleep extension week, on tasks of cognitive functioning, including tests of academic productivity, short-term memory and working memory.

Methods

Participants

All children in this study were recruited by newspaper/online ads, public posters, and public presentations. Past research participants who gave consent to be included in a recruitment database housed at Dr. Corkum's research laboratory were also contacted. The following inclusion criteria were used: 1) primary language is English; 2) no history of psychiatric illness; 3) no history of chronic uncontrolled physical illness impacting sleep; 4) no history of neurological impairments; 5) no known intrinsic sleep disorders such as sleep apnea; 6) do not regularly sleep less than 8 hours or more than 12 hours nightly, 7) not taking any medications that might affect sleep in the month preceding the study, and 8) not crossed more than two time zones in the last month. These inclusion criteria were used for inclusion in the larger study, however an additional criterion was used for the current study, whereby only children with completed teacher measures were eligible for inclusion. All children (n=20) were between the ages of 8 and 12, with a mean age of 9.75 years. The sample was made up of 12 females and 8 males.

Measures

A) Screening

1) Intake Screening Questionnaire (*ISQ; Vriend & Corkum, 2009*; *unpublished*). This screening questionnaire was completed over the phone with each participant's parent/guardian prior during the recruitment phase of the study. Each participant was asked 10 "yes" or "no"

questions based on the inclusion/exclusion criteria listed above. Nine of the questions had to be answered "no" for eligibility to participate and one question had to be affirmative. If the participant was deemed eligible for participation after this questionnaire was completed, a consent session was scheduled. See Appendix A for a copy of this measure.

2) Sleep Evaluation Questionnaire (SEQ; Mindell & Owens, 2003). The *SEQ* was completed by the parent at the baseline testing session. This measure was used as a secondary screening tool to obtain specific information about the participants' current sleep patterns and to ensure that children did not meet any exclusion criteria. The SEQ was also used to determine each participants' socio-economic status (SES) using the Hollingshead equation (Hollingshead, 1975). It required parents to answer questions about their child's sleep history, current sleep problems, medical and psychiatric sleep history, and school performance. Sleep items were rated on a 6-point scale: "never" if the behaviour did not occur and "always" if the behaviour occurred 6-7 times per week (See Appendix A for a copy of this measure).

B) Sleep Evaluation

Sleep duration was assessed using actigraphy and sleep diaries. Actigraph data and sleep diary data were used to determine the participants' typical bedtimes. The identified typical bedtime was then used to determine the bedtimes for the both sleep conditions (extension and restriction).

1) Actigraphy (Ambulatory Monitoring, Inc). Actigraphs are small watch-like devices worn on the wrist during sleep that measure frequency of movement and provide estimates of when the child falls asleep, when he/she wakes up, and also indicate sleep quality variables such as continuity and sleep efficiency. Children wore an actigraph every night for a total of 21 nights, seven nights for each week of the study (baseline, sleep extension week and sleep restriction

week). Actigraphy has been found to have good face validity and reliability, which has been documented in numerous studies. Studies have found a high rate of agreement (85-90 percent) between actigraphy and PSG, and actigraphs have been found to distinguish between sleep disturbed and control children with success (Ancoli-Israel, et al., 2003; Sadeh & Acebo, 2002).

2) Sleep Diaries (Corkum, 1996; unpublished). Parents were asked to complete a sleep diary for everynight that the child wore the actigraph. Sleep diaries were used primarily to aid in the scoring of the actigraph data by proving information on: 1) the bedtime routine (e.g., what time was first call for bed, what time were lights out); 2) initial sleep (e.g., how long did it take child to fall asleep); 3) middle sleep (e.g., number of night awakenings); 4) waking up (e.g., what time did child wake up, what time did child get out of bed); and 5) general sleep information and notes section. See Appendix B for a one-night sample of the sleep diary.

3) Child's Pictorial Sleepiness Scale (CPPS) (Maldonado, Bentley, & Mitchell, 2004). This scale displays five cartoon faces representing degrees of sleepiness. During each testing session, children were asked to indicate their sleepiness by circling the face that best matched how they felt at a particular time. This measure has good validity and is particularly useful with children (Maldonado et al., 2004). The CPPS was administered five times throughout the testing session, on each testing day (See Appendix B).

C) *Study Measures (See Appendix C)*

1) Cognitive Functioning. As a measure of academic productivity, a Math Fluency Test (MFT) based on the *Woodcock Johnson Tests of Achievement-III (Woodcock et al., 2001*) was used. This task measures speed and accuracy of mathematical computations by presenting each participant with a series of addition problems to complete in a 3 minute time period. Reliability

coefficients for this subtest range from .90 to .98 for children between 7 and 19 years of age (McGrew, Schrank, & Woodcock, 2007).

To examine memory, a task based on the Finger-Windows subtest of the *Wide Range Assessment of Memory and Learning (WRAML), Second Edition* (Adams & Sheslow, 1990) was used. This task requires the child to remember a visual pattern by watching the examiner point to asymmetrically located holes on an upright card. The child then duplicates the pattern and is subsequently presented with increasingly longer sequences. The finger-windows subtest has been found to have good internal consistency with Chronbach's coefficient alphas for children age 6-13 ranging from .81-.83 (Adams & Sheslow, 2003).

A digit-span task based on the Digit Span subtest of the *WISC-IV* (Wechsler, 2003) was also used as a measure of memory. In this task, children are asked to listen to a string of digits and then immediately recall in the correct sequence. The string of digits gets longer in a stepwise manner. For children aged 6-16, the digit-span subtest has been found to have good reliability, ranging from .78-.91 (WISC-IV Canadian Manual).

Each of the memory tasks had a forward task and a backward task. In the forward task, children responded by mimicking the exact sequence presented to them, whereas in the backward task, children had to respond by reversing the sequence presented to them. The forward task from each of the Finger-Windows task and the Digit Span task assessed short-term memory. The backward task from each of the Finger-Windows and the Digit Span task assessed working memory.

2) ADHD Symptomatology and Oppositional Behaviours. The *Conners' Rating Scale-Revised (Long Form) – (CRS; Conners, 1998),* which includes both a parent (CPRS; Conners' Parent Rating Scale) and teacher (CTRS; Conners Teacher Rating Scale) scale, were used to

examine the child's ADHD symptoms and oppositional behaviours at home and school each week the child participated in the study. The parent version consists of 80 items, whereas the teacher version has 59 items that assess behaviours associated with ADHD. Each item was rated on a 4-point Likert scale (0-3), where the parents and teachers provided ratings on a scale including "not true at all (never, seldom)", "just a little true (occasionally)", pretty much true (often, quite a bit)", or "very much true (very often, very frequent)". The CRS have been reported as having excellent internal reliability with coefficient alphas ranging from .75-.94 (Conners, Sitarenios, Parker, & Epstein, 1998). The subscales that were examined were the Oppositional scale and the ADHD Index. Each of these measures was completed at the end of each study week. If the ADHD Index scores were significantly different in the primary analysis, the Cognitive Problems/Inattention scale and the Hyperactivity/Impulsivity scale were examined as a secondary analysis.

The *RA ADHD Rating Scale (RA-ADHD Scale)* was also completed as a measure of attentional and behavioural functioning. The RA ADHD Rating Scale was an author-made scale, based on the DSM-IV criteria for diagnosing ADHD. The rating scale consists of 18-items (one for each of the 18 criteria included in the DSM-IV) that ask questions about the child's behaviour and attention during each testing session. The Research Assistant rates each question on a Likert scale from 0-3 as "never or rarely", "sometimes", "often", or "very often".

The participants in the study completed the *Self-Report of Symptoms Scale* (*Self-ADHD Scale*) questionnaire at the end of each testing session during the study. This questionnaire tapped into children's perceptions of their own behaviour with respect to ADHD (i.e., inattention, impulsivity, hyperactivity) and oppositional behaviours, as well internalizing states such as depression and anxiety. Participants rated each question on a Likert scale from 0-2 as

"never", "sometimes", or "often". For the current study, only the ADHD and oppositional scales were examined.

Procedure

After a recruitment initiative, interested families were encouraged to phone the research laboratory. The researcher returned calls within three days and if a family indicated interest in the study, a pre-screening interview ("Intake Screening Questionnaire") was scheduled over the phone. If inclusion criteria were met, a consent session was scheduled. Both the parent and the child were required to attend the consent session during which the study protocol was reviewed in detail. If both the parent and the child were interested in participating, the consent and assent forms were signed at the end of the session. A schedule for participation was created with the family, typically with a start date within two weeks following the consent session. The family was given an actigraph and a sleep diary, as well as parent and teacher questionnaires to take home. The family was also given the second screening measure, the Sleep Evaluation Questionnaire (Mindell & Owens, 2003) to complete at home and return at the baseline testing session. Upon arrival at the baseline session, research staff reviewed the questionnaire for any information about sleep that would meet exclusion criteria.

The first week of the protocol (Baseline week) began on a Saturday and the participant started wearing the actigraph 24 hours per day, while his/her parents completed the sleep diary each night of the week (Saturday through Friday). The child was asked to follow a typical sleep schedule over the baseline week and returned to the lab the following Saturday morning for testing at the pre-scheduled time. Upon arrival, the child returned the actigraph to a primary investigator and was set up in the testing room with a research assistant. The parent was given the weekly questionnaires to fill out during the testing session, in a room around the corner from

the testing room. The testing session took approximately two hours and involved completing a battery of tests, some of which were used in the current study, and others which were used in another study. There were two scheduled breaks for the child during the testing session and they occurred at the same time in the testing protocol each week. The child was also given a snack during the longer break. Please see Appendix D for a detailed list of activities. Research assistants completed the RA-ADHD Rating Scale at the end of each testing session.

At the baseline testing session, the actigraph data were analyzed to determine the participant's average bedtime and wake time. Two different sleep schedules were assigned to the family based on the baseline week data, one where the child's bedtime was reduced by one hour, and one where the bedtime was extended by one hour. The wake time remained consistent over the course of the study. Each participant was randomly assigned to have the restricted week first and the extended week second, or vice versa. For each experimental week, Saturday through Monday nights were typical sleep schedules, and the extension/restriction schedule was implemented the following Tuesday through Friday nights. Testing sessions always occurred on Saturday mornings and were identical to the baseline testing session. The family was informed of their randomization prior to leaving the baseline testing session and the schedule for the following week was reviewed with both the parent and the child, and written on the front page of the sleep diary. See Figure 1 for a diagram of the study design.

In addition to the sleep data being collected throughout the week, the participant's teacher also completed questionnaires on the child's behavioural functioning for each week of the study. Teacher forms were sent home with the family following the consent session, to be completed during the baseline week, and at the baseline visit additional forms were sent home for each of

the sleep manipulation weeks. It should be noted that research assistants and teachers were blind to the randomized condition of each child.

Once children had completed the three-week protocol they were awarded a certificate to thank them for their participation in the study. Parents were given the option to leave their address with the investigators so that a research summary could be sent to them upon completion of the study. Parents were also encouraged to contact the investigator if they had any questions about the research summary or about the research project in general. This research protocol was approved by the Mount Saint Vincent University Research Ethics Board (Project #2010-045), effective December 1, 2010. The larger study was approved by the IWK Health Centre REB (Project # 4520), effective September 28, 2010.

Data Analysis

The first step in the data analysis was to perform a paired samples t-test on the actigraph data to confirm that the sleep manipulation was successful. The dependent variable was sleep duration in minutes and the independent variable was experimental condition (e.g., extended sleep or restricted sleep). A paired samples t-test was also completed with the data from the Child's Pictorial Sleepiness Scale, where the dependent variable was the children's mean rating of sleepiness across 5 trials, and the independent variable was experimental sleep condition.

The second step of data analysis was to examine the objective and subjective data using repeated measures MANOVA. For the subjective data, the dependent variables that were analyzed were the oppositional behaviour subscale score and the ADHD index score from the CPRS, CTRS, RA-ADHD Scale, as well as the Self-ADHD Scale. The independent variable was experimental sleep condition (extended versus restricted sleep schedule). If the ADHD index was significantly different across the two sleep conditions, a paired samples t-test was completed as a

secondary analysis to further examine the impact of sleep manipulation on inattention and hyperactivity/impulsivity subscales individually.

The objective measures (academic productivity and memory) were analyzed using MANOVA, where the dependent variables for memory were short-term memory and working memory, and the dependent variables for the academic productivity were the number of questions completed, and the number of questions completed correctly. The independent variable was experimental sleep condition.

Given that this was a typically developing sample of children, the scores that were used for analysis were raw scores from the above measures, as raw scores, compared to standardized scores, are more sensitive to the subtle changes that would be expected in typically developing children. In order to aid in the interpretation of these raw scores, the range of possible raw scores is provided for each scale in the analyses below.

Results

Sample Characteristics

Data were collected from 20 typically developing children[1] from the Halifax Regional Municipality, Nova Scotia. All children were between the ages of 8-12 years with a mean age of 9.75 years. The sample was made up of 12 females and 8 males, all of whom were Caucasian. This study was part of a larger study and the assignment to sleep condition was random, however, not all of the participants in the larger study were eligible for the current study due to incomplete teacher data. Therefore, in the current study, 13 children had the extended sleep condition first, and 7 had the restricted sleep condition first.

[1] Power calculations were done for the larger study, and based on three studies examining sleep manipulation and cognitive performance in children (Gais, Lucas, & Born, 2006; Randazzo et al., 1998; Sadeh et al., 2003), a sample size of 15 participants was deemed sufficient to determine significance at alpha = .05.

The children in the sample had no diagnosed mental health disorders. One child had a diagnosis of diabetes, however, the child was stable and the diabetes was not interfering with the child's sleep. Examination of the children's family composition (taken from the SEQ), revealed that 17 of the 20 children were from two-parent households and three children were from single parent households (two divorced, and one widowed). In addition, 18 of the 20 children had siblings and only two children were only-children. Information on family socio-economic status was obtained from the SEQ and the majority of participants (80%) were from middle-to upper-class families.

With respect to the children's sleep history, none of the children in the sample had diagnosed sleep disorders. Examination of the SEQ, completed by the parents, revealed that none of the children were reported as having naps during the day, or any other sleep problems.

Sleep Manipulation

To determine the effectiveness of the sleep manipulation, a paired samples t-test was used to analyze the sleep duration from the actigraph data (See Table 1). The results indicated that at baseline, the children (n=20) were sleeping on average, 539 minutes per night (*SD = 24.31*)[2]. During the sleep extended condition, the children slept a mean of 564.26 minutes (*SD = 35.22*) per night, while during the sleep restricted condition, they slept a mean of 491.06 minutes (*SD = 36.83*) per night.

For the sleep manipulation to be successful, the aim was to have at least a 60 minute difference between the sleep extended and sleep restricted conditions. The paired samples t-test confirmed that children slept significantly less, 73 minutes, in the restricted condition than in the

[2] Baseline actigraph data for two of the participants were not available due to damaged actigraph files. Sleep Diary data were used to estimate the sleep duration for these two participants.

extended condition (t (19) = 8.70, p = 0.001), and therefore the sleep manipulation was considered successful.

To examine sleepiness during the testing sessions, a paired samples t-test was used to compare the means of the Child's Pictorial Sleepiness Scale. Results indicated that children rated themselves as significantly more sleepy during the testing session following the sleep restricted condition (t (19) = -3.84, p = 0.001) (See Table 2). The mean raw scores for sleepiness were 2.09 (SD = 0.62) for the sleep extended condition and 2.88 (SD = 0.95) for the sleep restricted condition (possible raw scores ranged from 0-5).

Impact of Sleep Manipulation on Daytime Functioning

a) ADHD Symptomatology and Behavioural Functioning

The first research hypotheses was that all informants (parents, teachers, child, and RAs) would report an increase in ADHD symptomatology and a decrease in behavioural functioning in the sleep restricted condition when compared to the sleep extended condition, indicating that less sleep is detrimental for attention and behaviour during the day. To examine this research hypothesis, four separate MANOVAs were completed to analyze differences in ratings of oppositional behaviour and ADHD symptoms based on the data collected from the CPRS, the CTRS, the RA-ADHD Scale, as well as the Self-ADHD Scale.

Parent Ratings: The MANOVA from the CPRS revealed an overall statistically significant difference between the parent reports during the sleep extended condition and the sleep restricted condition, (F (1, 19) = 5.36, p = 0.02). Examination of the univariate tests indicated that when children were sleep restricted they were rated significantly higher by their parents on the oppositional scale (F (1, 19) = 7.67, p = 0.01) as well as on the ADHD index (F (1, 19) = 6.02, p = 0.02). For the CPRS, the mean ratings on the oppositional scale were 3.40 (SD

= 3.25) for the sleep extended condition and 5.15 (*SD* = 3.31) for the sleep restricted condition (possible raw scores ranged from 0-29). For the ADHD Index, the mean raw score for children in the sleep extended condition was 5.10 (*SD* = 5.48), and 7.95 (*SD* = 7.85) for the sleep restricted condition (possible raw scores ranged from 0-36).

Given that the ADHD index scores were found to be significantly higher during the restricted week, a paired samples t-test was done to analyze the differences in the inattention and hyperactivity scales from the CPRS. Mean raw scores of inattention were 4.65 (*SD* = 4.83) during the sleep extended condition and 7.60 (*SD* = 7.24) during the sleep restricted condition (possible raw scores ranged from 0-36) and examination of the t-tests indicated that these were significantly different, (t (19)= -3.02, p = 0.007). The mean raw scores for parent rating of hyperactivity were 2.20 (*SD* = 3.29) for the sleep extended condition and 2.70 (*SD* = 3.25) for the sleep restricted condition (possible raw scores ranged from 0-26), which were not significantly different (t (19)= -1.13, p = 0.27).

Teacher Ratings: The results of the overall MANOVA for the CTRS were not significant, (F (1, 19) = 0.24, p = 0.79). Based on teacher report, mean raw scores for the oppositional scale were 0.30 (*SD* = 0.73) for the sleep extended condition and 0.45 (*SD* = 1.05) for the sleep restricted condition (possible raw scores ranged from 0-15). For the ADHD index, the mean raw scores were 2.40 (*SD* = 3.59) for the sleep extended condition and 2.60 (*SD* = 3.59) for the sleep restricted condition (possible raw scores ranged from 0-36).

Child Report: The overall MANOVA results for the child report measure were not significant (F (1, 19) = 0.26, p = 0.77). The mean raw scores for children's self reports of opposition were 3.00 (*SD* = 1.92) for the sleep extended condition, and decreased to 2.85 (*SD* = 2.11) for the sleep restricted condition (possible raw scores ranged from 0-12), while the mean

raw scores for the ADHD index were 9.70 (*SD* = 6.78) for the sleep extended condition, and 9.70 (*SD* = 6.20) for the sleep restricted condition (possible raw scores ranged from 0-18).

RA Ratings: The MANOVA from the RA-ADHD Rating Scale revealed an overall statistically significant difference between RA reports during each of the experimental sleep conditions (F (1, 19) = 4.22, p = 0.03). Descriptive statistics revealed that the mean ratings for the ADHD index increased from 2.55 (*SD* = 3.33) in the sleep extended condition, to 4.10 (*SD* = 5.24) in the sleep restricted condition (possible raw scores ranged from 0-18). Examination of the univariate tests indicated that this difference was statistically significant, (F (1, 19) = 5.28, p = 0.03). Mean raw scores for the cooperation scale were 1.00 (*SD* = 0.00) for the sleep extended condition and 1.15 (*SD* = 0.37) for the sleep restricted condition (possible raw scores ranged from 0-5), and these were not significantly different, however, they were approaching significance (F (1, 19) = 3.35, p = 0.08).

Given that the research assistants rated the children as having significantly higher scores on the ADHD index scores during the sleep restricted condition, a secondary analysis using a paired samples t-test was done to further examine inattention and hyperactivity scores. The mean raw scores for inattention were 1.05 (*SD* = 1.36) during the sleep extended condition, and increased to 2.40 (*SD* = 3.03) during the sleep restricted condition (possible raw scores ranged from 0-9). This change was statistically significant (t (19) = -2.24, p = 0.04). The mean raw scores for hyperactivity were 1.50 (*SD* = 2.37) for the sleep extended condition, and 1.70 (*SD* = 3.18) for the sleep restricted condition (possible raw scores ranged from 0-9). This change was not statistically significant (t (19) = -0.38, p = 0.71).

b) Cognitive Functioning

The second research hypothesis was that children would perform less well during their sleep restriction week, as compared to their sleep extension week, on objective measures of daytime functioning, including tests of academic productivity and memory. To examine this research question, a MANOVA was used to analyze differences in the children's working memory performance, short-term memory performance and academic productivity task (See Table 3). The overall MANOVA indicated that the children's performance on the measures of cognitive functioning was approaching significance (F (1, 19) = 2.91, p = 0.055) and therefore the univariate tests were examined (see below).

Short-Term Memory: Further examination of the univariate tests revealed that children's performance on the short-term memory tasks decreased from a mean score of 22.9 (SD = 4.21) in the sleep extended condition, to a mean score of 21.3 (SD = 3.79) in the sleep restricted condition (possible raw scores ranged from 0-40), and these means were found to be significantly different, (F (1, 19) = 4.37, p = 0.05).

Working Memory: Children's performance on the working memory tasks also decreased from 16.4 (SD = 3.26) in the sleep extended condition, to 15.3 (SD = 4.87) in the sleep restricted condition (possible raw scores ranged from 0-38), however this difference was not statistically significant (F (1, 19) = 1.35, p = 0.26).

Academic Productivity: Although the mean number of math problems completed during the extended condition was 51.9 (SD = 18.74), and decreased to 49.55 (SD = 18.90) in the sleep restricted condition (possible raw scores ranged from 0-96), the difference was not statistically significant (F (1, 19) = 2.66, p = 0.12). Similarly, the mean number of problems completed correctly was 50.6 (SD = 19.46) during the extended condition, and decreased to 48.8 (SD =

18.84) during the restricted condition (possible raw scores ranged from 0-96), however these results were also not significantly different, (F (1, 19) = 1.52, p = 0.23).

Discussion

The purpose of this study was to examine the impact of experimentally manipulating sleep on daytime functioning in a sample of typically developing children. Twenty children aged 8-12 participated in the study, and data were collected from parents, teachers, research assistants, and the children themselves on both subjective and objective measures of attention/behaviour, and cognitive functioning. Results indicated that children were successfully able to manipulate their sleep in either direction. Parents reported children as having increased attention difficulties and behavioural difficulties during the sleep restricted week. Research assistants, who were blind to experimental condition, also reported significantly increased inattention during the testing session for the sleep restricted week, whereas teachers and children did not report any significant changes in attention or behaviour. The children did rate themselves as feeling significantly sleepier during the testing session following the sleep restricted week compared to the sleep extended week. Childrens' cognitive functioning was also examined, and they demonstrated increased difficulty with short-term memory, however working memory was not significantly affected. Additionally, academic productivity was not significantly affected by reduced sleep.

The data from the objective measures of sleep indicated that at baseline, the children were sleeping, on average, 539 minutes (*SD = 24.31).* This suggests that even at baseline, children in this sample were getting less sleep than recommended for their age group (~9 hours versus the recommended 10-11 hours). When childrens' sleep was manipulated, the results indicated that on average, children were sleeping 73 minutes less in the sleep restricted condition than they were in the sleep extended condition, and this reduction resulted in sleepier children

(based on self-report). It was evident that children were able to successfully manipulate their sleep in both directions compared to baseline sleep. These findings were consistent with the findings from Sadeh et al., 2003 whereby children were randomized to either a sleep extension or sleep restriction protocol for three consecutive nights, and a difference of 76 minutes was found between the two conditions. Our findings, consistent with those of Sadeh et al (2003), imply that when children are given later bedtimes, their overall sleep duration decreases, and when children are encouraged to go to bed earlier, their overall sleep duration increases. Therefore, our results provide some support that children in general may be sleepier than they should be and that earlier bedtimes might address this problem.

The first research hypothesis was that parents, teachers, research assistants, and the children themselves, would observe increased attentional and behavioural difficulties during the sleep restricted condition as compared to the sleep extended condition. Consistent with previous research (Fallone et al., 2005), parents reported that their children had more difficulties with attention and behaviour during the sleep restricted week compared to the sleep extension week. Of particular interest, increases in ADHD symptoms were a result of increased inattention rather than increased hyperactivity/impulsivity. These findings indicate that when children were sleep restricted, parents found them more oppositional (e.g., increased whining, decreased compliance), and more inattentive (e.g., trouble focusing on tasks and completing tasks).

In contrast to the results based on the parent questionnaires, no significant differences in attention and behaviour were found across the two sleep conditions based on teacher reports. Fallone et al., 2005 is the only other experimental sleep study that examined teacher ratings of children and the findings were inconsistent with the current study. Teachers in Fallone et al.'s study did not rate children as demonstrating significantly increased difficulties with behavioural

functioning, however, they did rate attention problems as a significant main effect of sleep condition. The measure that was used may have been more sensitive to attention in the classroom setting, as it examined children's attention and concentration in 8 specific school based activities using a 9-point Likert scale as a measure of severity. The measure in the current study (CTRS) may have been too broad in nature as it collected information on many different indexes other than attention and behaviour, used a 3-point Likert scale as a measure of severity, and was not tied to specific classroom situations. Moreover, in classrooms of 25 or more children, where a subset of children have diagnosed learning disabilities, behaviour disorders, or other difficulties, it is plausible that the children in the current study did not capture the attention of their teachers as having increased difficulty compared to the other children in the classroom.

Given that teachers were blind to experimental condition and parents were not, the discrepancy in significant results between the two raises the question of whether there actually were changes in children's attention and behaviour, or whether parents were influenced by knowing the experimental condition. This is a possibility, given that qualitatively many parents expressed concerns with putting their children to bed an hour later than normal, as based on past experiences, they found their children more difficult to deal with when receiving less sleep. The anticipation of having difficulties with their children may have contributed to their significantly increased ratings of attention and behaviour problems in the sleep restricted week. It is also possible that parents observed decreased attention, and increased oppositional behaviours as they were interacting with their children in a more one-to-one setting, and perhaps the inattention and oppositional behaviours increased at times when children were more naturally tired (e.g., first thing in the morning, mid-afternoon, and bedtime).

Similar to the results from the parent data, the research assistant results yielded significant findings. The research assistants were blind to experimental condition, and had the unique opportunity to work with the children in a one-on-one setting after the maximum number of extended and restricted sleep days. The research assistants observed significant increases in symptoms of ADHD, particularly inattention as opposed to hyperactivity/impulsivity. This finding was especially interesting as the parents also rated inattention as being significantly higher during the restricted sleep condition. When we consider that both RAs and teachers were blind to experimental condition, the fact that RAs were able to note significant changes provides support for the hypothesis that perhaps the context in which teachers were observing children and the measure of these problems was not conducive to identifying changes across sleep conditions. Alternatively, both parents and RAs observed children in more one-on-one environments, with fewer other children in comparison.

The results from the child self-reports, like that of the teachers, did not reveal significant differences between the two sleep conditions. These findings suggest that although children were able to manipulate their sleep and reported themselves as feeling more sleepy, they did not notice any significant changes in their own attention or behaviour. Young children typically have not yet developed cognitive awareness of themselves, and where the mean age of this sample was relatively young (9.75 years), it is possible that they were not able to self-report on their own perceptions of behaviour.

In summary, the results from the subjective report data add to the existing literature by collecting information from multiple respondents. Parents and research assistants both observed significant changes in inattention across sleep conditions, whereas teachers and children did not. Additionally, parents also reported significant changes in behavioural functioning across

conditions. Interestingly, both RAs and teachers were blind to experimental condition; however, teachers did not observe any significant changes in the children in the classroom setting, whereas the RAs, in a one-on-one setting did observe significant changes. From this, we can speculate that although teachers are not reporting significant changes in attention and behaviour, it may be a result of the context in which they are observing the children and may be an underestimate of the impact that reduced sleep is having on children. Furthermore, the measures that were used for collecting data from parents, teachers, and research assistants are generally intended for clinical populations. Therefore, the significant findings from both parents and research assistants were particularly interesting as they were observing clinically relevant symptoms in typically developing children after only 4 nights of mild sleep restriction.

The second research hypothesis for the current study was that children would demonstrate decreased performance on tasks of cognitive functioning during the sleep restricted week compared to the sleep extended week. Overall, children in the current study demonstrated significantly more difficulty with their short-term memory during the sleep restricted condition as compared to the sleep extended condition, however there were no significant differences in their working memory or academic productivity across sleep conditions.

The results from the cognitive measures revealed that when children were sleep restricted, they had more difficulty with their short-term memory than they did when their sleep was extended. This finding is consistent with Sadeh, Gruber, & Raviv, 2003, where children in a sleep extended group demonstrated improved short-term memory on a Visual Digit Span task, whereas children who were sleep restricted and control children did not demonstrate significant improvements from baseline to post-intervention. These findings imply that the childrens' ability to immediately use newly learned information (short-term memory) was impaired when they

were sleep restricted compared to sleep extended. In the current study, in each task (Digit Span Forward and Finger-Windows Forward), the child had to either listen to, or watch as the RA presented the information (e.g., verbal or visual sequence). The child was then required to immediately recall the sequence exactly as it had been presented. It is possible that during the sleep restriction week, the children required more processing time to be able to correctly recall each sequence. Additionally, given that the children in the current study were reportedly more inattentive and more tired during the sleep restricted condition, it is possible that they had difficulty paying attention to the instructions that were required to perform the task.

Contrary to the effect on short-term memory, results from the current study indicated that working memory was not significantly affected by sleep manipulation. Interestingly, Randazzo et al., 1998 examined cognitive functioning in children who were sleep extended versus children who were sleep restricted (between subjects design) and found that there were no significant differences between the groups on measures of memory. Randazzo et al. (1998) hypothesized that the tasks were not highly demanding with respect to cognitive functioning due to their rote nature. One hypothesis for the results from the current study is that working memory is a core component of cognitive ability. The children in the current study were typically developing, and none were identified as having any cognitive impairments. Therefore we can assume that their cognitive abilities were relatively well developed. Furthermore, children's cognitive abilities are relatively stable over time, including their working memory ability. Given the short duration of the study, it is unlikely that performance on working memory was negatively affected by such a mild sleep manipulation.

In the current study, academic productivity was not significantly different when children were sleep restricted as compared to sleep extended. A possible explanation for these findings is

that the math fluency task required the children to perform math computations that were also rote in nature. Given that these children were typically developing, with no learning disabilities, their skills for rote tasks were likely well-developed and these skills were not affected by a mild sleep restriction. Additionally, low scores on working memory have also been specifically associated with poor computational skills in children (Gathercole et al., 2006). These findings provide evidence for a positively correlated relationship between working memory and math computation abilities. Therefore, because the children in the current study did not show significantly different working memory abilities across experimental sleep conditions, we can expect that their performance on the math fluency task was also not significantly affected. Finally, it is possible that the math fluency task that was not a strong measure of academic productivity. Given that the children in this sample were typically developing, it is likely that the task was not sensitive enough to examine differences in performance across sleep conditions.

Overall, the results indicated that children in the current study were demonstrating significant impairments in daytime functioning after mild cumulative sleep restriction when compared to sleep extension. These findings are concerning given that shortened sleep was found to cause problems with daytime functioning. Additionally, children are getting less sleep than recommended and are reporting themselves as feeling more sleepy. Overall these findings indicate that even after a mild sleep restriction of four nights, children were demonstrating impaired attention and behavioural functioning, as well as impaired cognitive functioning in the area of short-term memory. These findings are concerning as significant differences were observed after only 4 nights of cumulative sleep restriction.

Clinical Implications

This study involved only a mild cumulative sleep restriction in typically developing children with no learning disabilities, sleep problems, or behavioural disorders (e.g., ADHD, ODD). Significant impairments were found for both attention and short-term memory in the sleep restricted week compared to the sleep extended week. This implies that the impact of reduced sleep on daytime functioning for children who have diagnosed learning difficulties, attention problems, or sleep problems, may be even more remarkable. As noted previously, ADHD and sleep problems are highly linked, however the causal relationship is not clear. Given that typically developing children were observed as having difficulty with attention during the sleep restricted week as compared to the sleep extended week, we can speculate that a child with diagnosed attention problems (e.g., ADHD), who may already have difficulty sleeping, will demonstrate exacerbated problems with attention when sleep duration is reduced. Additionally, short-term memory was also found to be significantly affected during the sleep restricted week compared to the sleep extended week in the current study. As children progress through school, and the demands on memory abilities increase, the difficulties may impact other areas of cognitive functioning, such as working memory.

Children who do not get enough sleep during their elementary school years may also have difficulty with daytime functioning at school later on in their school careers. In the current study, teachers did not observe decreased attention during the sleep restricted week compared to the sleep extended week; however, given that parents and RAs did observe decreased attention, we cannot assume that children were not affected during the school hours. If their attention was impaired during the sleep restricted week, it is likely that they were not taking in all of the information presented to them during the school day. Although this is less of a concern in the

short term, if this pattern continued, it could lead to gaps in their understanding of skills necessary for academic achievement later on. If both attention and short-term memory are negatively impacted, it could be even more problematic for solidifying those necessary skills. Furthermore, as children progress through their school careers and the work becomes more cognitively demanding, the effects of impaired daytime functioning may be even more academically damaging.

Limitations

One of the most significant limitations of this study is the small sample size. This study was part of a larger study examining the impact of experimental sleep manipulation on emotional and attentional functioning in typically developing children. An inclusion criterion for the current study was complete teacher data, which was a limiting factor for the current study. Given that each participant made three visits to the laboratory, and testing sessions could only be held on weekends, time was limited as to the number of participants that were run during the school year, thus fewer participants had complete teacher data.

A second limitation was the nature in which the daytime data was collected. Although teachers were blind to experimental condition, it was not possible for them to directly observe the child multiple times throughout the day. This may have contributed to the lack of significant differences observed by teachers of children's attention and behaviour throughout the day.

A third limitation of this study was that parents were not blind to experimental condition. This may have impacted their ratings of attention, behaviour, as well as general impressions. Due to the ages of the children, it was necessary for the parents to know the condition as they were required to help their children follow the protocol. Furthermore, it was possible that having

children stay up an hour later than normal negatively impacted parents. The impact on parents was not examined in the current study; however, this could be done in the future.

A fourth limitation is that there may have been variation across research assistants in terms of ratings. However, the four research assistants that were employed in the current study were rigorously trained on the measures, and had lots of experience working with children in the research setting, with similar measures. To limit variation, the same research assistant was assigned to each participant for each of the sleep manipulation weeks. Additionally, a single research assistant ran the majority of participants.

A final major limitation to the current study was that the measures used for rating children may not have been sensitive enough for use in typically developing children. The CPRS and CTRS are both broad questionnaires exploring a spectrum of difficulties in children, and the measures of attention and behaviour within them may not have been sensitive enough to allow for significant differences across conditions, particularly for teachers in the school setting.

Future Directions

The varying results from the behavioural reports raises the question of how such studies as this one could be conducted to increase sensitivity in teacher reports. One way to address the discrepancy between parent, teacher and RA ratings could be to have research staff (blind to experimental condition) observe participants in the classroom setting and record information on children's behaviour, compliance, academic productivity, and social/emotional interactions. Observations could also be completed during the baseline week to obtain information on each child's typical classroom behaviour prior to the sleep manipulation.

Given the relationship between ADHD and sleep problems, in conjunction with the results from the current study, further experimental research in the area of sleep manipulation in

children with ADHD is critical. To address this gap in the literature, we will be building on the current research project by allowing a comparison group for participants with ADHD, so we can examine the impact of experimental sleep manipulation in children with ADHD. The results will be used to further our understanding of the relationship between sleep in children with ADHD, and will provide information on whether children with ADHD are affected by sleep restriction the same way as typically developing children.

Conclusions

The current research study was the first to include multiple informants (e.g., parents, teachers, RAs, and child self-reports) to examine the impact of experimental sleep manipulation on ADHD symptomatology and behavioural functioning. Overall, the results indicated that when children had reduced sleep compared to extended sleep, parents and research assistants both reported more attention difficulties. Parents also reported increased behavioural difficulties at home. On the other hand, teachers and children did not report significant changes in either ADHD symptomatology or behavioural functioning across manipulation weeks. Children were also demonstrating short-term memory difficulties during the sleep restricted week compared to the sleep extended week. Prior to experimentally manipulating sleep, the children in this study were already sleeping less than recommended. Although no studies have examined the long term impact of sleep restriction, we can speculate that children who are sleep deprived will continue to have difficulties with daytime functioning and that these may be exacerbated as the child becomes more chronically sleep deprived. It is important that the results of this study are shared with parents, health professionals, and educators, in order to raise awareness of the importance of sleep in school-aged children, as well as to illustrate the impact of reduced sleep on daytime functioning.

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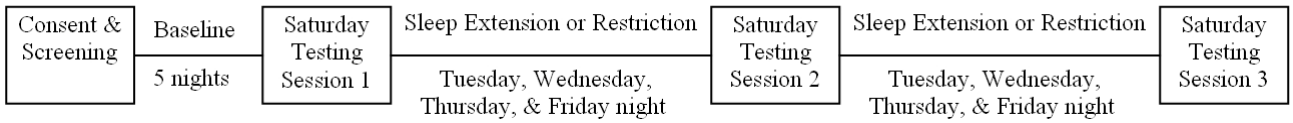

Figure 1. Sleep study protocol that each participant followed.

Table 1. Means (standard deviations) of sleep duration in minutes at Baseline and for each experimental sleep manipulation week.

	Baseline	Sleep Extension	Sleep Restriction
Sleep Duration (minutes)	539 (*SD = 24.31*)	564.26 (*SD = 35.22*)	491.06 (*SD = 36.83*)

Table 2. Means (standard deviations) of sleepiness rating from the Child's Pictorial Sleepiness Scale.

	Sleep Extension	Sleep Restriction	t	*p*
Sleepiness	2.09 (*SD* = 0.62)	2.88 (*SD = 0.95*)	-3.84	0.001 *

Table 3. Means (standard deviations) and ANOVA results for cognitive functioning.

	Sleep Extension	Sleep Restriction	F	*p*
Short-Term memory	22.9 (*SD* = 4.21)	21.3 (*SD* = 3.79)	4.37	0.05 *
Working memory	16.4 (*SD* = 3.26)	15.3 (*SD* = 4.87)	1.35	0.26
Academic Productivity – # completed	51.9 (*SD* = 18.74)	49.55 (*SD* = 18.90)	2.66	0.12
Academic Productivity – # completed correctly	51.9 (*SD* = 18.74)	49.55 (*SD* = 18.90)	1.52	0.23

Appendix A – Screening Measures

1) **Intake Screening Questionnaire**
2) **Sleep Evaluation Questionnaire**

1) Initial Screening Questionnaire

(Note: to be used in combination with the Sleep Evaluation Questionnaire)

Participant's ID#: _____ DOB: _____

Sex: Male Female

Inclusion/Exclusion Criteria

1. Is your child between 8 and 12 years of age?
   Yes No ⇨ if **no**, is **ineligible** to participate in study.

2. Does your child have a history of psychiatric illness (e.g., ADHD, anxiety, depression)?
   Yes No ⇨ if **yes**, **ineligible** to participate in study.

3. Does your child have a neurological condition (e.g., epilepsy, cerebral palsy, neuromuscular disease, severe visual impairment)?
   Yes No ⇨ if **yes**, **ineligible** to participate in study.

4. Does your child have a learning disorder?
   Yes No ⇨ if **yes**, **ineligible** to participate in study.

5. Does your child have a chronic serious illness?
   Yes No ⇨ if **yes**, **ineligible** to participate in study.

6. In the past month, has your child taken any medication, which might affect his/her sleep (e.g., medication for attention or behaviour)?
   Yes No ⇨ if **yes**, **ineligible** to participate in study.

7. Does your child have major sleep complaints (e.g., difficulties falling or staying asleep more than 3 nights per week)
   Yes No ⇨ if **yes**, **ineligible** to participate in study.

8. In the past month, has your child crossed more than two time zones?
   Yes No ⇨ if **yes**, **ineligible** to participate in study.

9. Does your child sleep an average of less than 8 hours or more than 12 hours nightly?
   Yes No ⇨ if **yes**, **ineligible** to participate in study.

10. Does your child regularly take naps (i.e., more than 2 naps per week)?
    Yes No ⇨ if **yes**, **ineligible** to participate in study.

3) Sleep Evaluation Questionnaire

A copy of this questionnaire is available in the research ethics office

Appendix B – Sleep Evaluation

4) **Sleep Diary (one night sample)**
5) **Child's Pictorial Sleepiness Scale**

Note: The Sleep Diary is printed on paper which is decorated with stars and moons

1. SLEEP DIARY

Participant's ID#: _____

Start Date: _____ End Date: _____

GENERAL INSTRUCTIONS

- Please leave diary in a convenient location
- It is important to fill out this diary on two occasions every day (evening and morning)
- Do not rely on your memory; rather fill out the diary as things happen
- Remember to press the event button on the "watch" at "lights out" and first wake up call
- If you have any questions please call _____ at _____

Penny Corkum, Ph.D.
Department of Psychology
Dalhousie University
902-494-5177

DAY 1

Date: _____

Did your child have the "watch" off today? (Please indicate times and reason)
_____
_____
_____

Getting Ready for Bed

First call to start to get ready for bed: _____ PM

What was he/she doing at this time:
___ watching T.V.
___ reading
___ computer/computer games
___ playing outside
___ other (please list: _____)

How did he/she react to the call for bed?
___ positively, no problems (e.g., no complaining, bargaining, etc.)
___ OK, a few problems
___ poorly, a lot of problems (e.g., lots of complaining, bargaining, etc.)

How many calls did it take before he/she began to get ready for bed: ____
What time did he/she begin to get ready for bed: ____ PM

Which activities did he/she have to do before going to bed:
___ getting pyjamas on
___ bath/shower
___ washing/brushing teeth
___ use the toilet
___ prepare for next day (choose clothing, pack school books)
___ other (please list: _____)

What time did he/she get into bed? ____ PM

What did he/she do after getting into bed and prior to "lights out":
___ have a book read by parent
___ read a book on own
___ listen to music
___ back rub, kiss/hug
___ parent needs to lie down with child
___ other (please list: _____)

What time was "lights out"? ____ PM
How did he/she respond to "lights out":
___ positively, no problems (e.g., no complaining, bargaining, etc.)
___ OK, a few problems
___ poorly, a lot of problems (e.g., lots of complaining, bargaining, etc.)

Initial Sleep

How many times did he/she call parent (but not get out of bed) prior to falling asleep? ____

How many times did parent need to respond? ____

How did parent respond?
___ limited or no response needed (e.g., call back to child, etc.)
___ moderate response needed (e.g., go to child's room to check on him/her, etc.)
___ a lot of response needed (e.g., stay in child's room, bring child to your room, etc.)

How many times did he/she get up after "lights out" prior to falling asleep? ___

How many times did parent need to respond? ____

How did parent respond?
___ limited or no response needed (e.g., call back to child, etc.)
___ moderate response needed (e.g., go to child's room to check on him/her, etc.)
___ a lot of response needed (e.g., stay in child's room, bring child to your room, etc.)

What reasons were given for getting out of bed:
___ had to use the washroom
___ hungry/thirsty
___ not tired
___ other (_____)

Approximately, what time did he/she fall asleep: ___ PM

Middle Sleep

Once asleep did he/she awake during the night: Yes No

How many times: ____

How many times did parent need to respond? ____

How did parent respond?
___ limited or no response needed (e.g., call back to child, etc.)
___ moderate response needed (e.g., go to child's room to check on him/her, etc.)

___ a lot of response needed (e.g., stay in child's room, bring child to your room, etc.)

What were the reasons for these night awakening(s):
___ bad dream/screaming out at night
___ had to use the washroom
___ hungry/thirsty
___ bed-wetting
___ sleep walking
___ awaken by someone else/noise
___ other

Waking Up

What time did he/she awaken this morning: ___ AM

How did he/she awake this morning (check all that apply):

___ Alarm
___ Parent
___ Combination of alarm and parent
___ On own
___ other (_____)

What time did he/she get out of bed this morning: ___ AM

If parent had to awaken him/her, how many calls did it take: ____

What time did your child have to leave the house this morning? ___ AM

Was it rushed to finish all the morning routines? Yes No

What was your child's mood upon awakening? (rate on the following five point scale)

good-natured				irritable
1	2	3	4	5
alert				lethargic
1	2	3	4	5

General Information

How would you rate your child's sleep last night compared to most nights:

typical				atypical
1	2	3	4	5

How would you rate your child's waking up this morning compared to most mornings:

typical				atypical
1	2	3	4	5

Please record any events which may have affected your child's sleep or waking up:

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

2. **Child's Pictorial Sleepiness Scale** (Maldonato, 2004)

Child's ID _____ Date _____

We are interested in finding out more about how sleepy you feel.
Please circle the face that best matches how sleepy you feel right now.
Thank you!

TIME: _____

TIME: _____

TIME: _____

TIME: _____

TIME: _____

Appendix C – Study Measures

1) **Cognitive Functioning**
    - Math Fluency task
    - Digit Span & Finger Windows
2) **ADHD Symptomatology and Behavioural Functioning**
    - Conners' Parent Rating Scale
    - Conners' Teacher Rating Scale
    - RA ADHD Rating Scale
    - Child Self-Report of Symptoms

1a) ACADEMIC PRODUCTIVITY - MATH SHEET

Participant ID: _____ Date: _____

Examiner: _____ Study Week: BL, Wk1, Wk2

4 +5	5 +9	3 +3	4 +9	1 + 6	3 +9
1 +2	8 +8	1 +1	6 +6	2 +5	7 +9
4 +6	5 +8	3 +5	6 +8	4 +4	7 +7
1 +5	2 +9	5 +5	4 +7	6 +7	1 +9
8 +9	1 +7	5 +6	4 +8	1 +4	7 +8
1 +3	2 +3	2 +4	5 +7	2 +6	3 +7
3 +6	3 +8	9 +9	2 +2	3 +4	2 +8
6 +9	2 +7	1 +8	2 +6	6 +6	4 +6

Page 2

2 +2	9 +9	5 +8	6 +8	1 +1	1 +8
6 +9	2 +7	2 +9	3 +6	2 +3	7 +8
1 +3	1 +4	4 +8	7 +9	8 +9	7 +7
3 +4	3 +7	5 +7	2 +8	2 +4	4 +7
5 +9	4 +4	2 +5	8 +8	3 +9	6 +7
1 +9	5 +5	3 +5	1 +6	1 +2	3 +8
3 +3	4 +5	1 +5	4 +9	1 +7	0 +0
1 +7	3 +3	6 +2	4 +4	3 + 4	7 +9

1b) **MEMORY TASK**

Digit Span - Forward

Participant ID: _____ Date: _____

Examiner: _____ Study Week: BL, Wk1, Wk2

Instructions: I am going to say some numbers. Listen carefully, and when I am through, you say them right after me.

Start: Item 1 (Administer one per second)

Discontinue: After failure on both trial 1 and 2.

Scoring: 2 points if the child passes both trials, 1 point if passes one trial, 0 points if fails both trials (include in the score items A-C, as well as 1-24 for a possible total of 27)

Trial		Trial Score	Item Score
1	2-9	0 1	0 1 2
	4-6	0 1	
2	3-8-6	0 1	0 1 2
	6-1-2	0 1	
3	3-4-7-1	0 1	0 1 2
	6-1-5-8	0 1	
4	8-4-2-3-9	0 1	0 1 2
	5-2-1-8-6	0 1	
5	3-8-9-1-7-4	0 1	0 1 2
	7-9-6-4-8-3	0 1	
6	5-1-7-4-2-3-8	0 1	0 1 2
	9-8-5-2-1-6-3	0 1	
7	1-6-4-5-9-7-6-3	0 1	0 1 2
	2-9-7-6-3-1-5-4	0 1	
8	5-3-8-7-1-2-4-6-9	0 1	0 1 2
	4-2-6-9-1-7-8-3-5	0 1	
		Total Score	

Digit Span - Backward

Participant ID: _____ Date: _____

Examiner: _____ Study Week: BL, Wk1, Wk2

Instructions: Now I am going to say some more numbers, but this time when I stop, I want you to say them backward. For example, if I say 8-2, what would you say?

- If correct, say "That's right".
- If incorrect, say "No, you would say 2-8. I said 8-2, so you say it backward; you would say 2-8.

Now try these numbers. Remember you are to say them backward: 5-6" (give no help on this one whether correct or not)

Start: Item 1 (Administer one per second)

Discontinue: After failure on both trials of one item.

Scoring: 2 points if the child passes both trials, 1 point if passes one trial, 0 points if fails both trials (include in the score items A-C, as well as 1-24 for a possible total of 27)

Trial		Trial Score	Item Score
Sample: 8-2			
5-6			
1	2-5	0 1	0 1 2
	6-3	0 1	
2	5-7-4	0 1	0 1 2
	2-5-9	0 1	
3	7-2-9-6	0 1	0 1 2
	8-4-9-3	0 1	
4	4-1-3-5-7	0 1	0 1 2
	9-7-8-5-2	0 1	
5	1-6-5-2-9-8	0 1	0 1 2
	3-6-7-1-9-4	0 1	
6	8-5-9-2-3-4-2	0 1	0 1 2
	4-5-7-9-2-8-1	0 1	
7	6-9-1-6-3-2-5-8	0 1	0 1 2
	3-1-7-9-5-4-8-2	0 1	
Total Score			

Finger Windows – Forward

Participant ID: _____ Date: _____

Examiner: _____ Study Week: BL, Wk1, Wk2

Instructions: This card has holes like windows. I am going to put the end of my pencil into one window and then another. When I am done, I want you to do the same thing with your finger. Let's try one. Wait to I say "Begin" before you start.

Start: Item 1 (Administer one per second)

Discontinue: After 3 consecutive errors

Scoring: One point for each correct sequence

	Forward	Score 0 or 1
A	3	
B	1	
C	7-9	
1	1-7	
2	3-6	
3	7-9-8	
4	3-1-7	
5	6-5-2	
6	1-7-9-3	
7	3-5-4-8	
8	9-5-8-6	
9	8-5-4-7	
10	4-5-2-6	
11	2-4-7-3-1	
12	7-6-8-9-2	
13	7-5-4-8-2	
14	2-8-4-5-7	
15	5-7-2-6-4	
16	1-3-7-4-2	
17	4-5-7-2-8-4	
18	3-6-5-4-1-2	
19	6-5-9-4-3-2	
20	1-9-3-6-7-5	
21	5-4-8-2-8-4-5	
22	9-6-5-8-3-9-1	
23	3-1-6-9-7-3-5-6	
24	3-5-2-9-6-5-8-4	
	Total Score	

Finger Windows - Backward

Participant ID: _____ Date: _____

Examiner: _____ Study Week: BL, Wk1, Wk2

Instructions: Now, I am going to put my pencil through some more windows, but this time when I stop, I want you to do them backwards. For example, if I do this (2-4), what would you do? If correct, say "That's right". If incorrect, say "No, you would do this (4-2). I did this (2-4), so you do it backward; you would do this (2-4). Now try these ones. Remember you are to do them backward."

Start: Item 1 (Administer one per second)

Discontinue: After 3 consecutive errors

Scoring: One point for each correct sequence

Backward			Score 0 or 1
		Answer	
A	2-4	4-2	
B	7-9	9-7	
C	1-3	3-1	
1	3-9	9-3	
2	1-5	5-1	
3	1-3-2	2-3-1	
4	9-7-1	1-7-9	
5	7-9-4	4-9-7	
6	5-8-6-2	2-6-8-5	
7	1-6-2-9	9-2-6-1	
8	3-5-4-6	6-4-5-3	
9	7-6-9-4	4-9-6-7	
10	9-5-2-7	7-2-5-9	
11	4-5-3-1-7	7-1-3-5-4	
12	1-6-4-5-2	2-5-4-6-1	
13	9-6-8-7-2	2-7-8-6-9	
14	3-9-4-6-8	8-6-4-9-3	
15	9-8-5-4-6	6-4-5-8-9	
16	7-9-8-6-4	4-6-8-9-7	
17	1-6-8-3-9-5	5-9-3-6-1	
18	1-4-6-8-5-7	7-5-8-6-4-1	
19	7-5-8-1-2-3	3-2-1-8-5-7	
20	3-7-1-5-6-4	4-6-5-1-7-3	
21	6-4-8-1-9-5-4	4-5-9-1-8-4-6	
22	7-5-4-6-9-8-1	1-8-9-6-4-5-7	
23	9-7-6-1-3-5-4-2	2-4-5-3-1-6-7-9	
24	1-6-2-7-8-5-3-9	9-3-5-8-7-2-6-1	
		Total Score	

2A) ADHD SYMPTOMATOLOGY AND BEHAVIOURAL FUNCTIONING - CONNERS' PARENT RATING SCALE-REVISED (LONG FORM)

A copy of this questionnaire is available in the research ethics office

2B) ADHD SYMPTOMATOLOGY AND BEHAVIOURAL FUNCTIONING - CONNERS' TEACHER RATING SCALE-REVISED (LONG FORM)

A copy of this questionnaire is available in the research ethics office

2C) ADHD SYMPTOMATOLOGY AND BEHAVIOURAL FUNCTIONING - RA ADHD RATING SCALE

Attention Rating Scale – Testing Observations

Participant ID: _____ Date: _____ Examiner: _____

Circle the number that best describes this child's behavior during the testing session.

		Never or Rarely	Sometimes	Often	Very Often	Not Applicable
1.	Fails to give close attention to details or makes careless mistakes.	0	1	2	3	N/A
2.	Fidgets with hands or feet or squirms in seat.	0	1	2	3	N/A
3.	Has difficulty sustaining attention in tasks or play activities.	0	1	2	3	N/A
4.	Leaves seat when remaining seated is expected.	0	1	2	3	N/A
5.	Does not seem to listen when spoken to directly.	0	1	2	3	N/A
6.	Runs about or climbs excessively.	0	1	2	3	N/A
7.	Does not follow through on instructions and fails to finish work.	0	1	2	3	N/A
8.	Has difficulty playing or engaging in leisure activities quietly.	0	1	2	3	N/A
9.	Has difficulty organizing tasks and activities.	0	1	2	3	N/A
10.	Is "on the go" or acts as if "driven by a motor."	0	1	2	3	N/A
11.	Avoids tasks (e.g., schoolwork, homework) that require sustained mental effort.	0	1	2	3	N/A
12.	Talks excessively.	0	1	2	3	N/A
13.	Loses things necessary for tasks or activities.	0	1	2	3	N/A
14.	Blurts out answers before questions have been completed.	0	1	2	3	N/A
15.	Is easily distracted.	0	1	2	3	N/A
16.	Has difficulty awaiting turn.	0	1	2	3	N/A
17.	Is forgetful.	0	1	2	3	N/A
18.	Interrupts or intrudes on others.	0	1	2	3	N/A

Circle the number that best describes this child's mood during the testing session.

19.	Happy				Sad
	1	2	3	4	5
20.	Cooperative				Uncooperative
	1	2	3	4	5
21.	Relaxed				Anxious
	1	2	3	4	5
22.	Alert				Tired
	1	2	3	4	5

2D) ADHD SYMPTOMATOLOGY AND BEHAVIOURAL FUNCTIONING – CHILD SELF-REPORT OF SYMPTOMS

(See next page)

SELF REPORT OF SYMPTOMS (CHILD)

Date: _____ Participant ID: _____

Examiner: _____ Testing Session (circle): Baseline, Wk 1, Wk 2,

INSTRUCTIONS: *In the last week, how much have you done each of the things I'm going to ask you – NEVER* [point to card]*, SOMETIMES* [point to card]*, or USUALLY* [point to card].

	Never	Sometimes	Usually
1. Rushed through your school work and didn't pay close attention to what you were doing.	**0**	**1**	**2**
2. Squirmed around in your seat or fidget and played with your hands or your feet.	**0**	**1**	**2**
3. Had a hard time sticking to one activity when you were at school or playing at home.	**0**	**1**	**2**
4. Got up out of your seat during class or during homework.	**0**	**1**	**2**
5. Had trouble listening when other people were talking to you (e.g. Teacher, parent).	**0**	**1**	**2**
6. Felt restless, like you needed to keep moving.	**0**	**1**	**2**
7. Had trouble following the teacher's directions, or trouble finishing your work.	**0**	**1**	**2**
8. Made a lot of noise when you were playing and doing activities that you like.	**0**	**1**	**2**
9. Had a hard time finding everything you needed to do your work or play a game.	**0**	**1**	**2**
10. Were always "on the go", always doing something or moving around a lot.	**0**	**1**	**2**
11. Didn't enjoy, or tried to get out of, doing things that you have to really think about, like reading.	**0**	**1**	**2**
12. Talked too much, way more than other kids.	**0**	**1**	**2**
13. Lost the things you needed to do work at school, or homework, or to play games at home.	**0**	**1**	**2**
14. Gave answers before the other person finished asking the question, or without raising your hand.	**0**	**1**	**2**
15. Were distracted by little things going on that had nothing to do with what you're doing (e.g. like noises in the room).	**0**	**1**	**2**
16. Had a hard time waiting for your turn.	**0**	**1**	**2**
17. Forgot to do some of the things you do everyday (e.g. like chores, routines, etc.).	**0**	**1**	**2**
18. Started talking before other people finished, or butted into the things they were doing.	**0**	**1**	**2**
19. Lost your temper.	**0**	**1**	**2**
20. Argued with grown-ups.	**0**	**1**	**2**
21. Broke the rules or wouldn't do something a teacher or parent asked you to do.	**0**	**1**	**2**
22. Bothered other people on purpose.	**0**	**1**	**2**

24. Got annoyed by other people really easily.	**0**	**1**	**2**
25. Felt nervous.	**0**	**1**	**2**
26. Worried that you're not going to be good enough at something in school or at home.	**0**	**1**	**2**
27. Worried that something bad would happen.	**0**	**1**	**2**
28. Felt scared.	**0**	**1**	**2**
29. Felt bad about yourself.	**0**	**1**	**2**
30. Had trouble getting rid of worries.	**0**	**1**	**2**
31. Felt really sad.	**0**	**1**	**2**
32. Didn't like doing your favorite things as much as you usually do.	**0**	**1**	**2**
33. Felt like crying.	**0**	**1**	**2**

Comments/Observations

For Office Use Only

Attention _____ Anxiety _____

Hyperactivity _____ Depression _____

ODD _____

Appendix D - Testing Protocol for Sleep Manipulation Study

Testing Battery

- Memory Tasks (15 minutes)
  - Digit Span forward and backward
  - Finger Windows forward and backward
- Academic Productivity (5 minutes)
  - Math Sheet
- **SNACK and BREAK**
- Child Self-Report of Symptoms
- Pictorial sleepiness scale (5 times throughout testing session)

Forms for Tester

- RA ADHD Rating Scale

Forms for Parent

- Sleep Evaluation Questionnaire (Baseline only)
- Conners' Parent Rating Scale – Revised
- Sleep Diary (completed at home)

Forms for Teacher

- Conners' Teacher Rating Scale – Revised