

Abstract

Title of Dissertation: The Effects of Natural Sleep Debt on Current Mood, Working Memory, and Risk-Taking Propensity

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It has been established that, as a whole, adolescents receive inadequate amounts of sleep due to both biological and environmental influences. As a result of this sleep loss, daytime impairment may occur in both cognitive and affective domains. Recent evidence suggests that inadequate sleep may also play a role in increased risk taking behavior, however, these studies are primarily descriptive in nature. Given that adolescents may be at particular risk for engagement in increased risky behaviors due to chronic insufficient sleep, more rigorous studies focusing on this relationship may be useful. To address this need, the current study provides a laboratory-based examination of sleep debt and risk-taking behavior using a multi-modal assessment approach. This association will be evaluated directly using a behavioral assessment task that measures risk-taking propensity as well as indirectly by examining several dimensions of the construct of disinhibition, which is purported to underlie risk-taking behaviors. Additionally, this study seeks to replicate past findings that suggest a link between sleep debt and daytime impairment in the form of decrements in working memory and disturbance of current mood states. It is expected that this research will provide a better understanding of the relationship between sleep debt and risk-taking behaviors, setting the stage for future studies.

The Effects Of Natural Sleep Debt On Current Mood, Working Memory, And
Risk-Taking Propensity

By

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Dedication

This work is dedicated to my mother, Barbara J. Hall, for her endless encouragement and support throughout this process. She put her life on hold to allow me to pursue my dream and no words could ever express the enormous gratitude that I have for her sacrifice. She has been a true inspiration and a blessing in my life.

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Chapter 1: Theoretical Rationale

Overview of Sleep

The exact function of sleep in our daily lives is unclear; however, it has been established that it serves as a restorative process, which has been shown to be particularly important during periods of brain maturation (Campbell et al. 2007; Tononi & Cirelli, 2003). Although, the human sleep system is multifaceted, the following review will focus on processes by which sleep operates and the characteristics that differentiate the stages of sleep. A basic knowledge of these two aspects of sleep is important because it serves as a precursor to understanding how adolescent sleep changes and how these changes relate to behavioral manifestations.

Two intrinsic mechanisms have been found to interact with one another to account for sleep and many of the psychological and physiological phenomena associated with it. The first mechanism that is quite diffuse and involves many regions of the brain can be referred to as sleep/wake homeostasis (or process S) and is responsible for the initiation and maintenance of sleep during the first several hours of the night. The most obvious effect is that the longer an individual stays awake the greater the pressure there is to sleep (Borbely, 1982; Wyatt, 2004). The second mechanism is the circadian timing system (or process C), which is situated in the suprachiasmatic nuclei. This system has been commonly referred to as an individual's "biological clock". This clock is made up of a small group of neurons responsible for endogenous oscillating circadian rhythms that are synchronized with the 24-hour day. In addition to promoting sleep and wakefulness, this timing system

has been shown to regulate many internal functions such as core body temperature, cortisol and melatonin secretion, and thyroid stimulating hormone release.

Environmental factors that play a role in these biological processes include exogenous Zeitgebers or “time cues” that signal changes in the sleep/wake cycle. The primary environmental method of entrainment of biological circadian rhythms is through daily light-dark cues. However, several weaker social zeitgebers exist as well. A phase relationship between these Zeitgebers and the circadian timing system exists on an approximate 24-hour schedule consistent with the 24-hour day. Social zeitgebers are especially relevant to examine with regard to the adolescent population given the increase in social demands and the elevated sensitivity to social influence.

The second aspect of sleep that will be reviewed includes the various stages of sleep and the neurobiological processes associated with them. In 1953 Aserinsky and Kleitman discovered rapid eye movement (REM) sleep, which led to the distinction between non-rapid eye movement (NREM) and REM stages of sleep. NREM was further subdivided into stages 1-4, where a greater “depth of sleep” is associated with the higher numbers (Erman, 2001; Roth 2004). Stage 1 of NREM sleep has been related to a transition from wakefulness into drowsiness and entry into sleep. Easy arousal by auditory, visual, or tactile stimulation is characteristic of this stage. Stage 1 accounts for approximately 5%-10% of total sleep time in healthy adults (Quereshi & Lee-chiong, 2004; Smith, Hurd, Cracraft, Hyslop, Zgheib, & Hoffert, 2006). Stage 2 occurs throughout the total sleep period, transitioning into delta wave sleep. In this stage, arousal is more difficult as with the subsequent stages. Stage 2 represents 40%-50% of total sleep time in healthy adults (Erman, 2001, Smith, Hurd, Cracraft,

Hyslop, Zgheib, & Hoffert, 2006). Stages 3 and 4 (slow wave sleep), comprise approximately 20% of total sleep time in healthy adults and can be distinguished by the percentage of delta wave activity that occurs during these periods (20%-50% and 100% respectively). Throughout these two stages, growth hormone is secreted by the pineal gland, which encourages bone and muscle growth in children as well as tissue repair in adults. This combination of slow, strong delta waves and hormonal activity has been found to have restorative effects (Smith, Hurd, Cracraft, Hyslop, Zgheib, & Hoffert, 2006). The final stage in the sleep cycle is REM sleep. In this stage muscle paralysis occurs along with rapid eye movements and brain activity similar to what is found during “awake” periods. A single REM cycle lasts approximately 20 to 30 minutes. REM sleep is characterized by increased blood flow to the brain, genital activity, and dreams (Quereshi & Lee-chiong, 2004; Smith, Hurd, Cracraft, Hyslop, Zgheib, & Hoffert, 2006).

Research suggests that REM sleep may play a vital role in various forms of daytime function. For example, several researchers have used human analogue studies to show that REM sleep is important for learning such that it increases when new material has been acquired and that learning is impaired during REM deprivation (Hennevin, Hars, Maho, & Bloch, 1995; Smith, 1995). In addition, it has been suggested that one night of sleep deprivation can significantly reduce prefrontal metabolic activity which has been associated with decrements in performance on tasks requiring complex cognitive processing (Thomas et al., 2000). Using an anagram task, Walker and colleagues (2002) found that REM sleep was associated with increases in cognitive flexibility in a sample of college undergraduates.

Specifically, REM was associated with a 32% advantage in the number of anagrams puzzles solved compared to Non-REM. A study by Rauchs, Bertran, Guillery-Girard, et al. (2004) revealed that REM sleep, which primarily occurs in the second half of the night, is involved in the consolidation of episodic memory. Using a sample of 43 young adults aged 18-26, they found that REM-sleep deprivation was associated with significantly lower recall of spatial information and was also associated with a higher forgetting rate of temporal information as compared to stage 4 sleep deprivation that occurs primarily in the first half of the night. However, this literature has not been extended into the child literature as thoroughly. Relatively few studies involved adolescent populations despite the fact that they are chronically sleep deprived and often suffer from some form of daytime impairment.

Sleep Loss

Now that a basic understanding of fundamental sleep processes has been established it is necessary to discuss specific types of sleep loss as they relate to clinical practice. The three specific types of sleep loss that are most commonly studied include sleep deprivation (total sleep loss), sleep restriction (decreased total sleep time), and sleep fragmentation (sleep disruption). Although often used very loosely, in technical terms, sleep deprivation indicates that sleep has been completely withheld either experimentally or as a result of exogenous circumstances. In contrast both sleep restriction and sleep fragmentation refer to partial sleep loss through either, eliminating chunks of sleep or disrupting sleep frequently by natural or experimental methods. Sleep restriction can either be acute or cumulative in that a large portion of

sleep can be withheld all at once or small amounts of sleep can be withheld over a period of time. Similarly in sleep fragmentation sleep can be interrupted often, as few as several times throughout the night, or in conjunction with the commencement of specific stages of sleep. Natural forms of sleep fragmentation can be found in patients with sleep disorders such as sleep apnea and periodic limb movement disorder (Bastuji & Garcia-Larrea, 1999; Moore et al, 2001; Van Son, Hofman, Van Uffelan, 2000). Sleep disruptions include physically unobservable partial arousals monitored through EEG as well as full arousals visibly evidenced through an awakened state. Sleep loss can be monitored subjectively and objectively through the use of self-report measures, sleep logs, sleep diaries, actigraphy, and polysomnography (Haba-Rubio, Ibanez, Sforza, 2004; Hedner et al., 2004; Honomichl et al., 2002; Morgenthaler et al., 2007).

Sleep Loss and Changes in Adolescence

In general, adolescence has been characterized as a time of great change in human development. Research has targeted the sleep/wake cycle and biological circadian rhythms that lead to phase shifted sleep as two such life-altering changes. It has been suggested that puberty and environmental influences can lead to alterations in the endogenous timing system, often resulting in delays in the onset of sleep and shifting of the overall sleep/wake cycle (Carskadon et al., 1993; 1997; Laberge et al., 2001). This phase shift can result in considerable sleep loss that has been linked to emotional, cognitive, and behavioral dysfunction in adolescence.

Sleep loss in the adolescent population has become increasingly problematic and prevalent. It has been estimated that approximately 25% of adolescents report having one or more symptoms related to a disorder of sleep (Ohayon, et al., 2000). In particular, research has shown that insomnia (difficulty with the onset and/or maintenance of sleep) and delayed sleep phase syndrome, (a persistent pattern of late sleep onset and late awakening times, with an inability to fall asleep and awaken at a desired earlier time; APA, 2000), appear to be common and chronic in the adolescent population (Dagan & Eisenstein, 1999; Johnson et al., 2006; Ohta, 1995). Lifetime prevalence rates for insomnia have been shown to range from 4% to 11% with 88% of those with a history of insomnia reporting current episodes (Johnson et al., 2006; Ohayon et al., 2000). With regard to delayed sleep phase syndrome, a study by Dagan and Eisenstein (1999) reported the characteristics of 56 patients suffering from a circadian rhythm disorder compared to their non-disordered counterparts and found that 83.5% of the sleep disordered patients suffered from delayed sleep phase syndrome and of that group 89.6% reported that the onset of their disorder occurred in early childhood or adolescence. In general, the prevalence for formally diagnosed delayed sleep phase syndrome ranges from 0.25% to 7%, however the suspected incidence rate of this condition is likely higher in the general adolescent population (Ando, Kripke, & Ancoli-Israel, 1995; Ohta, 1995; Pelayo, Thorpy, & Glovinsky, 1998; Wyatt, 2004).

Biological factors. High prevalence rates of insomnia and delayed sleep phase syndrome in the adolescent population has led recent research to focus on the possible associations between biology and sleep loss. Adult and basic research

studies have uncovered relationships between sleep loss and changes in brain gene activity, medical conditions such as Parkinson's, as well as maturation (Young et al., 2007; Gjerstad et al., 2007; Maret et al., 2007; Montemitto et al., 2008). In a study by Maret and colleagues (2007) using inbred mouse strains it was revealed that diurnal changes in gene transcription might be sleep/wake dependent and that the consistent activation of the Homer 1a gene after sleep loss suggests a role for sleep in intra cellular calcium homeostasis, a process that has been linked to recovery following persistent neuronal activity. A second study by Gjerstad et al., (2007) used a sample of 231 adults with Parkinson's disease that were evaluated for REM sleep behavior disorder. Of the 89 that were followed for the full 8 year period, REM behavior disorder ranged in frequency from 14.6% to 27% with increase probability of REM behavior disorder linked to higher levels of dopamenergic treatment. This suggests that higher levels of dopamine may contribute to REM behavior disorder. In general, biological changes that have been linked to adolescent sleep loss specifically include increased need for sleep, less time in slow-wave sleep, more time in stage 2 sleep, longer latency to rapid-eye-movement sleep, a propensity towards a delayed sleep phase, and variable timing in the secretion of melatonin (Brock, 1991; Campbell et al., 2007; Carskadon & Davis, 1989; Carskadon et al., 1993; Carskadon et al., 1997; Johnson et al., 2006; Laberge et al., 2001; Millman, 2005; Myers & Badia, 1995). Carskadon and colleagues have produced several studies supporting this biological link. In one study they sampled 458 sixth graders using self-report measures to investigate whether or not an association existed between puberty and delayed phase preference. They found that a significant relationship existed in the

female students but not in the males sampled (Carskadon et al., 1993). They attempted to explain this finding by suggesting that the gender distinction may be attributed to maturational differences exhibited in early adolescence. In a second study by this group, sleep patterns of 19 children were sampled using a "long nights" protocol and revealed that the offset phase of melatonin secretion was significantly correlated with age and Tanner Stage, an indicator of pubertal development (Carskadon et al., 1997). A study by Laberge and colleagues (2001) followed 1,146 youths from age 10 through 13 using self-reported measures of sleep. They found that nocturnal sleep times decreased with age, bedtimes were increasingly delayed with age, and differences between weekend and school day sleep schedule increased with age. Additionally, gender and puberty were linked to differences in timing of sleep on the weekends. Most notably puberty was associated with an increased physiological need for sleep.

Environmental factors. Environmental factors that have been associated with sleep loss in adolescence include parental involvement (i.e. less involvement in bedtime routine and less overall parental monitoring), earlier school schedule, peer socialization pressures, emotional reactivity, extracurricular activities, academic responsibility, electronic media, and employment (Carskadon, 1990; Carskadon, 1999; Millman, 2005). Research has shown that parental involvement in establishing a bedtime decreases with age, however, their involvement in morning wake-up increases (Mitru, Millrood, Mateika, 2002; NSF Poll, 2006; Teufel, Brown, & Birch, 2007). Although it has been established that adolescents have a somewhat decreased need for sleep when compared to their much younger counterparts, 9-10 hours of

sleep per night is still optimal. However, high school start times are earlier than elementary or secondary school start times causing adolescents to wake up earlier despite generally going to bed later due to a biological shift. This shortened period of available sleep time reduces the average amount of adolescent sleep to approximately 6 hours per night and has been related to an increase in daytime somnolence in this population (Carskadon, 1990), perhaps beyond what is already evidenced through pubertal changes. Additionally, peer socialization, a psychosocial factor related to sleep loss, becomes extremely important in adolescence as the child attempts to gain autonomy from parents and is more susceptible to peer influence. Heightened anxiety and depressed mood are factors that are common during the teenage years and can alter the onset as well as amount of sleep an adolescent obtains. This alteration can occur through excessive rumination related to anxiety effecting sleep onset or through difficulty with sleep maintenance associated with depression. Increased opportunities to participate in extracurricular activities and academic pressure associated with college aspirations and or school district placement can be linked to sleep loss through time demands. Technological advances such as computers, televisions, video games, and telephones that teens generally have liberal access to also play a role in adolescent sleep loss. Van den Bulk (2004) used a sample of over 2,500 adolescents aged 13-17 to investigate the association between sleep loss and mass media. Through the use of self-report measures results showed that watching television, computer game playing, and internet use were all associated with going to bed later on weekdays as well as weekends, waking up later on the weekends, less time in bed, and higher levels of overall tiredness. With regard to employment, data from the

National Sleep Foundation 2006 Sleep in America Poll shows that 18% of adolescents who obtained insufficient amounts of sleep during the weekdays (i.e. <8 hrs) were employed at a job where they work 10 hours or more. A study by Carskadon (1990a) also revealed that two thirds of high school students have jobs and approximately 30% worked 20 hours or more. Additionally the students that work at least 20 hours reported that they had later bedtimes, shorter sleep times, more frequent falling asleep in school, more frequent oversleeping and increased late arrivals.

Additive effects of biological and environmental factors. Research suggests that both biological and psychosocial factors interact to produce a schedule of inadequate sleep common in the general adolescent population (Carskadon, 1990a). It has been revealed that the aforementioned factors can result in relatively small amounts of reduced sleep each day of the week generally starting at the beginning of the week and ending on Fridays (Anders et al., 1978; Carskadon & Davis, 1989; Klackenberg, 1982). Among other things, this consistent loss of sleep can lead to daytime somnolence that increases in magnitude as the week progresses. This build-up of sleepiness has been referred to as a sleep debt that accrues by weeks end and can be considered a natural form of cumulative sleep restriction (Andrade et al., 1993; Arakawa et al., 2001; Millman, 2005; Strauch & Meier, 1988; Wolfson, 1996). Further research on this topic has revealed that on weekends, adolescents have a tendency to “catch-up” on sleep by extending their total time in bed so that it is greater than what they receive on weekdays (Lagerge et al., 2001; Petta et al., 1984). This extension is hypothesized to relieve the sleep debt created throughout the week

allowing the adolescent to start out the week relatively rested (Anders et al., 1978; Carskadon & Davis, 1989; Klackenberg, 1982; Wolfson, 1996).

Sleep debt has been associated with several functional changes. These changes in adults include increased subjective sleepiness, fatigue, confusion, tension, and total mood as well as decreased vigor (Dinges et al., 1997). Decrements in neurocognitive functions such as working memory, attention, and impulsivity have also been associated with sleep debt (Dinges et al., 1997; Herscovitch & Broughton, 1981; Rosenthal, Roehrs, Rosen, & Roth, 1993; Taub & Berger, 1973). Finally a compensatory reaction in response to inadequate sleep has been revealed by Drummond and colleagues (2004) such that areas of the brain that typically underlie cognitive function exhibit increased activation while other areas, typically dormant, begin to activate during this period, with the areas of activation mediated by task difficulty. The primary cerebral areas of note include the parietal lobes as well as the temporal cortex and prefrontal cortex.

Daytime Impairment Associated with Sleep Loss in Adolescence

Despite this effort to extend sleep on the weekends to mitigate the effects of sleep loss during the week, most adolescents consistently obtain inadequate levels of total daily sleep (Carskadon, 1989; Millman, 2005). Several forms of daytime impairment have been attributed to persistent sleep loss across the lifespan. Those most often associated with adolescence can range from mild behavioral changes to severe life threatening acts. A technical report by the American Academy of Pediatrics revealed that decrements in school performance related to excessive

daytime somnolence (EDS), mood disturbance, and increased engagement in risky behavior serve as possible costs of adolescent sleep loss (Millman, 2005). These costs will be explored further in the following paragraphs.

Cognitive performance. Cognitive decrements have been linked to sleep loss primarily through tests of executive function, attention, and working memory, as well as through results of academic performance. Overall, a review of the literature by Durmer and Dinges (2005) indicated that studies investigating the effects of sleep deprivation repeatedly show a variable negative impact on mood, cognitive performance, and motor function due to an increasing sleep propensity and destabilization of the wake state. In particular, Sadeh, Gruber, and Raviv (2002; 2003) have conducted two studies that repeatedly show decrements in neurobehavioral functioning as a result of sleep loss. Most recently they studied the effects of modest sleep restriction and extension on the neurobehavioral functioning of 77 school-aged children and found that moderate changes in sleep duration have significant detectable effects on neurobehavioral functioning.

When specific areas of cognitive function are examined in the adult literature, consistent decrements have been revealed, however, the child and adolescent literature has been variable. For example, adult studies assessing working memory and its connection with sleep loss have shown that sleep debt can lead to working memory deficits. A study by Van Dongen et al. (2003) used a sleep debt paradigm to compare dose response-effects on neurobehavioral function. Results showed that subjects exhibited escalating numbers of lapses in behavioral alertness, as well as decreasing cognitive accuracy (including performance on a test of working memory),

and speed across a 14-day period. Belenky and colleagues used a sample of 66 adults to assess the affects of 3 hrs, 5 hrs, 7 hrs, and 9 hrs of sleep on participant performance using the psychomotor vigilance task. Results revealed a similar dose response effect whereby higher levels of restriction were more indicative of decreased reaction time and lapses in performance. An additional finding of this study revealed that a recovery period of 3 days with 8 hours total sleep time was enough to increase the level of performance in the severely restricted group however the level of functioning in the 3 hr, 5 hr, and 7 hr groups never reach baseline during that time period. This suggested that a greater recovery period might have been needed for levels of functioning to return to baseline in those three groups. Another study used a sample of 17 adults who underwent 24 hours of sleep deprivation while monitored using polysomnography (Thomas et al., 2000). In addition, the subjects were asked to perform a serial addition and subtraction task while being scanned using positron emission tomography to examine the relationship between sleep loss and working memory. Results indicated that a decrease in glucose metabolism was found in the thalamus as well as the prefrontal and posterior parietal cortices, which was associated with decrements in alertness and cognitive performance.

Inconsistencies in the child and adolescent literature suggest that the type of sleep loss as well as type of cognitive function that is assessed may influence deficits in working memory. Two teams under the direction of Carskadon (1981a, b) found decrements in memory after a full night of sleep deprivation but not after an acute sleep restricted period. In the study showing decrements, 12 adolescents underwent an extensive 6-day sleep deprivation protocol and found that performance was

consistently impaired in the domains of speed & accuracy as well as recall. Additionally Randazzo and colleagues (1998) found that the type of cognitive task made a difference in whether significant results were found. Children aged 10-14 who had undergone sleep restriction in a laboratory setting were compared to their non-restricted peers. The restricted group received 5 hours of sleep as opposed to the control group that received 11 hours of sleep. Results showed that the restricted group exhibited impairment in tests of verbal creativity (i.e. fluency, flexibility, and average indices) and in learning abstract concepts as measured by the Wisconsin Card Sorting Task. However, on tests of verbal memory, visual memory, learning, recall and problem solving no significant changes were found.

In terms of academic impairment, research shows that decrements in school performance have also been revealed after periods of restricted sleep through lower letter grades and increased incidence of failure (Aguilar et al., 2006; Wolfson & Carskadon, 2003). This compromise in cognitive performance has also been shown to be exacerbated by excessive daytime somnolence (EDS), a byproduct of inadequate sleep. Research suggests that adolescents who obtain inadequate sleep have a tendency to fall asleep in class as well as during other inappropriate daytime events, struggle with staying awake while driving, and have reduced alertness associated with daytime somnolence (Carskadon, 1989; Carskadon et al., 1998). A study by Shin and colleagues (2003) investigated sleep habits, daytime somnolence, and school performance in a sample of 3,871 Korean high school students. Their results were consistent with previous findings in that students were going to bed late (35% after midnight) and waking up early (53% woke up before 7:00 am). They

found that on average the students were receiving approximately 6 hours of sleep a night when 9-10 hours is what is considered most appropriate for this age group (Carskadon et al., 1980; Mercer, Merritt, Cowell, 1998; Millman 2005). Using the Epworth scale they revealed that approximately 15% of their total sample reported EDS with higher prevalence rates for females (18%) as compared to males (15%). With regard to school performance they found that as a whole, lower grades were significantly related to EDS when compared to students earning moderate and high grades. When prevalence rates were gender specific, similar trends were found. The prevalence of EDS in males significantly increased with academic decline and the highest prevalence of EDS was found in females with lower grades.

Mood disturbance. Affective changes have also been linked to sleep loss (Carskadon & Acebo, 2002; Dinges et al., 1997; Gau, Soong, Merikangas, 2004; Meney et al., 2001; Mikulincer et al., 1989; Van Dongen, Baynard, Maislin, Dinges, 2004). Some of these changes include increased depressed mood, suicidal ideation, increased anxiety, fatigue, and irritability. However, a bi-directional relationship has been suggested. When studies have examined the impact of depression on sleep, research shows that up to 95% of patients with major depressive episode have at least one complaint of sleep disturbance including difficulties with sleep onset, sleep maintenance, and early awakening (Hamilton, 1989; Thase, 1999). Additionally, the Diagnostic and Statistical Manual for psychiatric disorders fourth edition revised (DSM-IV-TR; APA, 2000) lists sleep disturbance as a neurovegetative sign for depression and other mood based psychiatric disorders. Some research studies have also shown this effect through the use of healthy subjects who exhibit depressive like

symptoms through experimental manipulation. One such study was based on the findings that sleep in depression can be characterized by sleep fragmentation, reductions in slow wave sleep, and disinhibition of REM sleep (Berger, van Calker, & Riemann, 2003). This study found that by administering cholinomimetics (a proxy for neurochemistry changes found in depressive patients) disinhibition of REM sleep was provoked in healthy participants and strengthened in depressed participants.

Furthermore research by Oyane and colleagues (2008) investigated the relationship between seasonal changes in mood/behaviors and sleep. This study revealed that high and moderate levels of seasonality as measured by the global seasonality scale were significantly associated with insomnia and higher levels of daytime somnolence compared to the low seasonality group. Seasonality was also linked to shorter sleep duration as well as greater subjective sleep need.

When examining this relationship from the perspective of sleep influencing mood, a cross-sectional study by Scott, McNaughton & Polman (2005) found that sleep deprivation was associated with significantly greater negative disturbances to subjective vigor, fatigue and depression. A more rigorous experimental investigation by Dinges et al. (1997) utilized a sleep debt protocol with a sample of 16 young adults, with a mean age of 23. The sleep debt was induced in a tightly controlled, laboratory based setting by restricting nocturnal sleep onset and early morning awakening by equal amounts such that the subjects were restricted to approximately 5 hours of sleep across a span of 7 days. This type of restriction mimics what is naturally found in real-world settings. The participant's sleep was monitored using both subjective and objective methods throughout the restriction phase. These

methods include behavioral observation, sleep logs, and wrist actigraphy. Cognitive performance and mood were assessed at three time periods each day, consistent with morning, afternoon, and nighttime schedules. Several significant results were revealed. To begin with, elevations in subjective sleepiness as measures by the Stanford Sleepiness Scale (SSS; Hoddes et al., 1973) and in various subscales of the Profile of Mood States (POMS; McNair, Lorr, & Druppleman, 1971) were evident. Those subscales include fatigue-inertia, confusion-bewilderment, tension-anxiety, as well as total mood. Decreases in vigor were also revealed. Additionally, significant linear trends in subjective sleepiness, fatigue, vigor, confusion, tension and total mood disturbance were established from the second baseline day throughout the restriction period. Finally subjective sleep showed significant increases across the restriction segment as well as time of day effects. Specifically, subjective sleepiness was most pronounced at 10:00 am and increased from baseline day 2 to day one of restriction, remained the same from day 1 through day 6 of restriction, then significantly increased again on day 7. The latter findings are important because they confirm that one night of sleep restriction is adequate to cause significant changes in subjective sleepiness and after 7 consecutive days the feeling is even more robust.

In the adolescent literature the same bi-directional associations have been found especially in terms of anxious and depressive symptomatology. With regard to anxiety, research by Alfano, Beidel, Turner, & Lewin (2006) showed a relationship between anxious youths and increase rates of sleep complaints. Their data showed that 83% of purely anxious children and adolescents had at least one intermittent sleep complaint with approximately half of the anxious sample reporting frequent

problematic sleep. Additionally, evidence suggests that adolescents with clinical mood disorders have higher rates of disordered sleep (Birmaher, 1996; Dahl et al., 1996; Millman, 2005). For example, a study by Dahl and colleagues (1996) revealed that at baseline depressed adolescents had prolonged sleep latency and reduced REM latency compared to non-depressed controls. Likewise, children with sleep disorders or impairing symptoms of sleep have reported persistent mood disturbance including negative and depressed mood states (Dahl & Lewin, 2001; Millman, 2005; Morrison, McGee, Stanton, 1992; Rao et al., 1996; Schrader, Bovim, Sand, 1996). For example Wolfson and Carskadon (1998) recruited a sample of 3,120 high school students to examine the association between sleep habits and daytime functioning. Results showed that students with shorter weekday total sleep time and with larger bedtime weekend delays reported increased daytime sleepiness, depressive mood, and increased sleep wake behavior problems as compared to their peers with longer total sleep and less than a 60 minute weekend delay. Finally Agargun and Cartwright (2003) revealed that scores of adolescent suicidality were negatively correlated with REM latency and that a positive correlation between suicidality and REM percent existed such that suicidal subjects had a significantly shorter mean REM latency and a higher mean REM percentage than the non-suicidal subjects.

Risk-taking behavior. The extant literature with regard to sleep loss as it relates to mood disturbance and decrements in cognitive function has been fairly well established including both observational and experimental studies. In contrast, the same cannot be said regarding risky behavior. However, before the literature linking

sleep and risky behavior is reviewed, it is imperative to understand the multifaceted construct of disinhibition and how this variable underlies risky behavior.

Factors Underlying Risk-Taking Behavior

By definition, risky behaviors are considered to be any behavior that increases the risk of morbidity and or mortality (Irwin & Millstein, 1986). These behaviors include but are not limited to those that contribute to unintentional injury and violence, tobacco use, alcohol and other substance use, and sexual behaviors that contribute to unintended pregnancy and sexually transmitted diseases (STDs). The Center for Disease Control (CDC; Eaton, 2005) estimated that 71% of all deaths among persons age 10 to 24 result from motor vehicle crashes, other unintentional injuries, homicide, and suicide as compared to those aged 25 or older where 61% of deaths result from cardiovascular disease and cancer. Specifically with regard to adolescents, in the 30 days preceding the CDC survey 9.9% of high school students surveyed had driven a car or other vehicle when they had been drinking alcohol, 18.5% had carried a weapon, 43.3% had drunk alcohol, and 20.2% had used marijuana. In addition, it was reported that 2.1% of high school students had injected an illegal drug and 46.8% of high school students had had sexual intercourse. More importantly, of that group 37.2% had not used a condom during their last encounter (Eaton et al., 2005).

Given the high propensity for adolescent engagement in risky behavior it is necessary to investigate the processes by which this phenomenon occurs. Several theories have been proposed to explain the underlying mechanisms of risk-taking

behavior. Among those theories, personality variables have played a prominent role. For example Cloninger's personality theory posits that behavioral activation, behavioral inhibition and behavioral maintenance are all brain systems that relate to heritable personality dimensions (Cloninger, 1987, Cloninger, Sigvardsson, Pryzbeck, & Svrakic, 1995; Sher, Bartholow, & Wood, 2000). Within those dimensions, harm avoidance, reward dependence, and novelty seeking have been found to correlate highly with risky behaviors like alcohol dependence and substance abuse. In particular novelty seeking has been associated with impulsive and disinhibited types. Eysenck also proposed a personality theory that has been linked with risk-taking behavior. Specifically, high scores on his psychoticism and neuroticism dimensions have been linked to alcohol abuse through personality traits such as impulsivity and moodiness (Eysenck & Eysenck, 1977; Kilbey, Downey, Breslau, 1998; Sher, Bartholow, & Wood, 2000).

Another useful framework for considering risk behavior is behavioral disinhibition. In the past, using stimulus-response terminology, behavioral disinhibition has been characterized as a temporary loss of inhibition caused by an outside often unrelated stimulus (Pernanen, 1997). However more recently, in a laboratory-based study by Hirshfeld-Becker and colleagues (2002), the term behavioral disinhibition was operationalized as a "tendency to explore novelty, to readily approach unfamiliar stimuli, and to display disinhibition of speech or action." Research has shown that this propensity can be conceptualized across several lower order factors including impulsivity, sensation seeking and risk taking propensity (Krueger, Caspi, Moffitt, Silva, & McGee, 1996; Lejuez et al., 2002; McGue, Slutske,

& Iacono, 1999; Sher, Bartholow, & Wood, 2000; Zuckerman, Eysenck, & Eysenck, 1978). Following from this work, Krueger et al., (2002) proposed a hierarchical model of externalizing disorders such that one broad category of what has been termed “externalizing” is hypothesized to capture a spectrum of lower order personality traits and psychopathology that often co-occur. The model is constructed in such a way that the overarching category is thought to influence all the specific syndromes it encapsulates while allowing for unique variance between the individual syndromes. Specifically, their data showed that disinhibitory personality traits often co-occur with alcohol dependence, drug dependence, conduct disorder, and adolescent antisocial behavior all of which can be linked to a highly heritable externalizing factor. Thus this theory provides a solid foundation for the association between disinhibited personality traits and risky behaviors.

Impulsivity

One lower order factor contributing to the construct of disinhibition is impulsivity. In general research has shown that adolescents who engage in risky behaviors exhibit significantly higher impulsiveness (Carroll et al., 2006; Kingsburry et al., 1999; Moore & Roesenthal, 1993; Vitaro et al., 1998) and that those who are impulsive by nature are more likely to engage in risky behaviors (Cooper et al., 2003; Devieux et al., 2002; Vitacco & Rogers, 2001). A study by Cooper et al. (2003) used 1,978 adolescents to investigate the relationship between personality and risk behavior. Analyses of data from several self-report measures revealed that impulsivity and avoidance coping served as generalized risk factors for risky

behaviors such as delinquent behavior, substance use, and sexual behavior.

Furthermore, a study by Mischel et al., (1989) sampled 4-year old children and found that self-control in children was positively associated with adolescent social and intellectual competence, while impulsiveness was associated with aggressive and delinquent behavior.

Impulsivity is a multidimensional construct that encompasses various specific types of behavior. For the purposes of this study three dominant models of impulsivity will be discussed. The first model relies on a delay discounting paradigm where impulsivity is defined as choosing a smaller more immediate reward in the face of a larger more delayed reward where the amount of the delay is related to the amount of discounting in a hyperbolic fashion (Monterosso & Ainslie, 1999; Reynolds & Schiffbauer, 2005; Swann et al., 2002). The delay-discounting literature suggests that generally speaking substance abusers discount the value of the delayed reinforcement to a greater extent than their non-abusing counterparts (Bickel & Johnson, 1993). Additionally, there is further evidence to suggest that discounting may be adaptable and that a critical period for this adaptation may exist (Bickel, Odum, & Madden, 1999; Heil, Johnson, Higgins, & Bickel, 2006).

The second model has been characterized as a rapid response model, or non-planning, where impulsivity is defined as responding without adequate assessment of context. A study by Enticott, Ogloff, and Bradshaw (2006) used the Stroop task, a behavioral measure, to evaluate non-planning in relation to self-reported impulsivity. In a sample of 31 adults, results revealed that the Stroop task significantly correlated with non-planning, attentional, motor, and overall self-reported impulsiveness.

Additional studies using self-report measures such as the Eysenck Personality Inventory (EPI; Eysenck, Pearson, Easting, & Allsopp, 1985) have found similar results. The EPI is a well-validated self-report measure that breaks down into two distinctive personality traits, Extraversion and Neuroticism (Eysenck et al., 1985). The extraversion trait has been found to consistently correlate with impulsivity, which the Eysencks define as acting on impulse or non-planning. Research by Carroll et al. (2005) investigated the association between impulsivity and Juvenile delinquents using the Stroop task and the EPI self-report measure. Results suggested that adolescents who displayed rapid cognitive tempo, poor mental inhibitory control, and high impulsivity were more likely to be early-onset offenders as compared to late-onset and non-offending peers.

The third and final model is described as the pre-potent responding model where impulsivity relates to the inability to inhibit a response after an initial response has been given. This is often measured through stop tasks and go/no-go tasks. Logan, Schachar, and Tannock (1997) utilized the stop task to evaluate 136 students on impulsivity and pre-potent responding. Their data revealed that students who scored high on impulsivity scales had longer stop-signal reaction times than their low impulsive peers.

Sensation seeking

Another form of disinhibition lies in the construct of sensation seeking. Sensation seeking refers to an individual difference in optimal levels of arousal and stimulation, manifested as a character dimension and regulated by neurotransmitters

such as dopamine and norepinephrine (Zuckerman, 1990, 1994). Plainly stated it can be considered an individual's need to seek out novel and thrilling experiences and the willingness to take risks to obtain them. In general, research shows that individuals who are high in sensation seeking are more likely to be involved in risk-taking behavior. Sensation seeking has been linked to engagement in a multitude of different risk-taking behaviors. Involvement in dangerous sports, risky sexual practices, gambling, alcohol and substance use/abuse, as well as risky driving are just a few of the behaviors that have been associated with sensation seeking (Ball, 1995; Crawford et al., 2003; Donohew et al., 1999; Cloninger, Sigvardsson, & Bohman, 1988; Newcomb & McGee, 1989; Sheer and Cline, 1994). A research team lead by Greene (2000) investigated sensation seeking and found that sensation seeking combined with high personal fable predicted risk-taking behaviors in adolescents. A second study by Tremblay et al., (1994) revealed that higher novelty-seeking in children was associated with subsequent delinquency. Similarly, Vitacco and Rogers, (2001) used an adjudicated sample of 79 males and found that conduct disordered symptoms were predicted by impulsivity and sensation seeking.

Although it is typical for sensation seeking to be viewed as a stable personality trait that is associated with some outcome, a handful of studies have looked at sensation seeking as a fluctuating state that could be considered dependent upon within subject change or experimental manipulation. For example a study by Stanton et al., (2001) used a sample of 383 African American adolescents to examine the relationship between early initiation of sex, increased drug use, drug trafficking, and sensation seeking using the modified version of the Zuckerman sensation seeking

scale (SSS). The subjects were followed longitudinally over the course of 4 years using a serial risk assessment battery and the SSS. Results indicated that youths who reported tobacco, alcohol, and marijuana use had higher sensation seeking scores during follow-up assessments as compared to baseline. This study suggests that it may be possible to view sensation seeking as a variable that could be influenced by context. Theoretically speaking it is also plausible to think about fluctuations in ones optimal level of arousal being linked to changes in other regulatory functions such that one's optimal level of arousal may increase to some extent to compensate for a change in dopaminergic pathways or prefrontal cortex activity (Romer & Hennessey, 2007).

Risk-taking propensity

Finally risk-taking propensity can be viewed as an individual's proclivity towards seeking out and or engaging in risky events. It is a construct often used as an analogue to real world risky behavior in laboratory settings. Several behavioral tasks have been used to examine the relationship between risk taking propensity and real-world risk taking as well as with other types of disinhibition. One such task is the Balloon Analogue Risk Task (BART; Lejuez et al., 2002). This task has been shown to correlate with other measures of disinhibition as well as with actual risky behavior in adults. Additionally, more recent studies have extended the scope of this task to the adolescent population resulting in similar findings. A study by Lejuez et al. (2002) found that the BART was significantly correlated with scores on measures of sensation seeking, impulsivity, and deficiencies in behavioral restraint in adults.

Another study by Hunt et al. (2005) used the BART with college age students to examine the associations of psychopathy and impulsivity with individual risk taking propensity. Results indicated that higher self-reported psychopathy was significantly predictive of higher levels of risk-taking behavior on the BART. In addition, a study by Lejuez and colleagues (2003) explored the use of the BART as a predictor of real-world risk taking in an adolescent population. Their results showed that the BART was significantly correlated with self-report of real world risk taking behaviors as measured by the Youth Risk Behavior Surveillance System (CDC, 2001).

In short, risk taking is a behavior that is prevalent in the adolescent population and the process by which this behavior manifests itself can be discussed in terms of behavioral disinhibition. Furthermore behavioral disinhibition can be broken down into various component parts (i.e. impulsivity, sensation seeking, and risk-taking propensity) that serve as mechanisms of action in this process.

Sleep and Risk-Taking Behavior

Now that the fundamental personality concepts underlying risk taking have been explored, the literature linking risk-taking behavior to persistent sleep loss can be reviewed in context. To date, few studies have examined the relationship between inadequate sleep and risk-taking behavior in a controlled laboratory environment, however there have been several correlational studies that have examined the relationship between sleep loss and specific types of risky behavior such as driving/riding while drunk, suicidality, alcohol use/abuse as well as other forms of substance use/abuse (Carskadon, 2002; Liu, 2004; Wong, Brower, Fitzgerald, &

Zucker, 2004; Zwyghuizen-Doorenbos et al., 1988). Evidence suggests that adolescents who experience inadequate sleep may also engage in risky driving habits such as driving while drowsy (Carskadon, 2002; McConnell, Bretz, & Dwyer, 2003). A study by Carskadon and Wolfson (1989) examined the association between the time spent participating in extracurricular activities/work related commitments and risky/dangerous behavior in a sample of 2,293 adolescents. Two critical findings were revealed. First, those that incurred greater time commitment as a result of extracurricular activities and or working, obtained less overall sleep than those who had fewer commitments. Secondly, those with time intensive commitments were more vulnerable to sleep/wake behavior problems. Most recently, O'Brian and Mindell (2005) investigated the link between sleep/wake patterns and adolescent risk taking behaviors. They analyzed self-report measures taken from 388 adolescents and found that adolescents who reported shorter weekday total sleep time and longer weekend delay reported significantly higher levels of risk taking behaviors. However, both studies relied solely on cross-sectional analyses of self-report measures as opposed to using an experimental or naturalistic design and integrating behavioral assessment strategies.

Although this area of study is in it's infancy there are several important ways in which sleep and risk-taking behaviors may be linked that require further research and collaboration across fields of study. For example from a neuroscience standpoint there is evidence to suggest that the prefrontal cortex maybe an area in which regulation of risky behavior may be linked (Steinberg, 2008). Additionally, changes in prefrontal cortex activity have been associated with extended periods of sleep

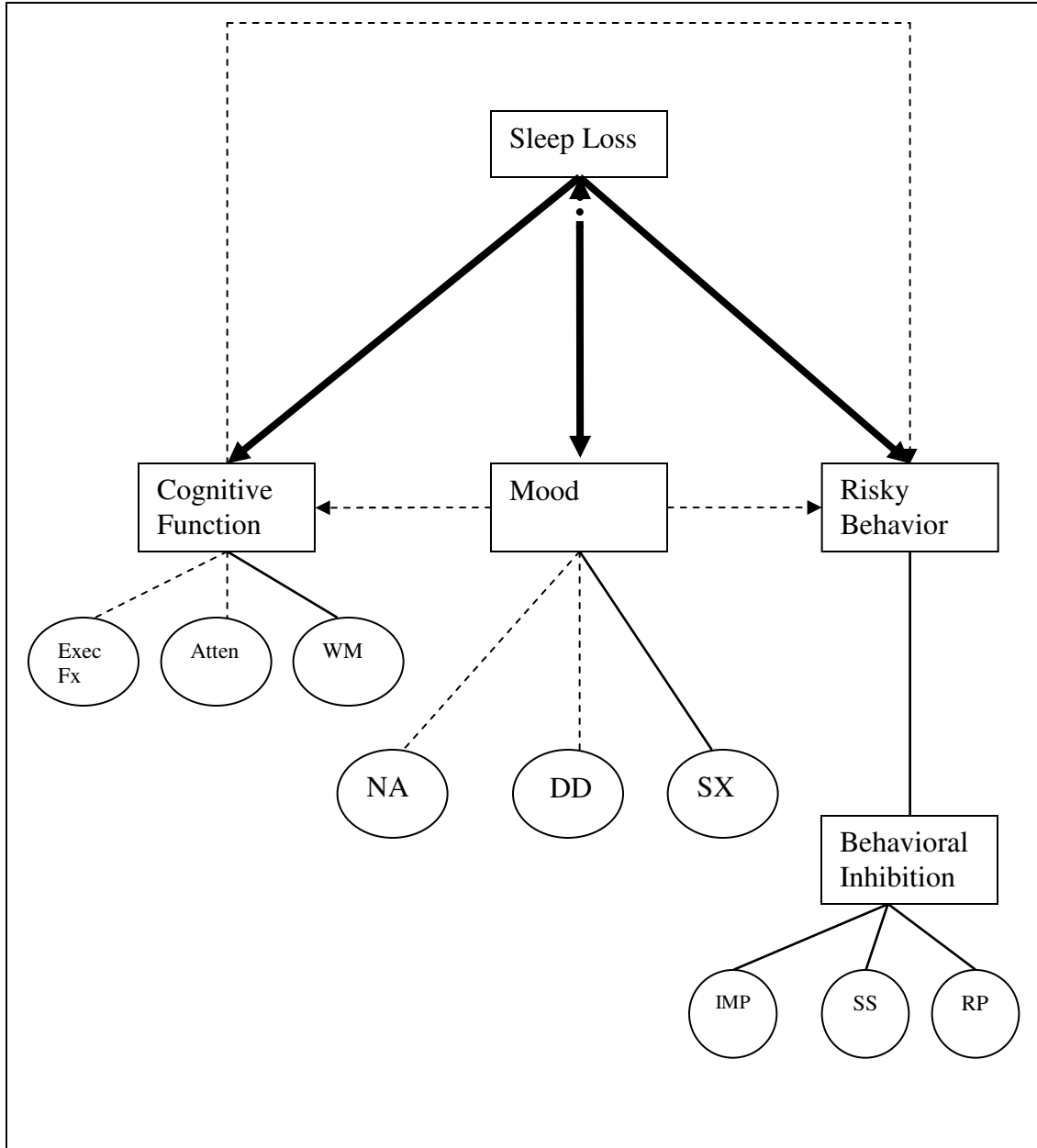
deprivation. From this it is possible to suggest that an underlying mechanism may exist that links increased risk behavior and sleep loss through changes in prefrontal cortex activity. Another possible theory would be to suggest that the two may be related through personality variables and individual difference factors that may make one more vulnerable to the effects of sleep loss which manifests itself in increased engagement in risky behavior given the right context. Finally there may be mediation by mood whereby the lack of sleep may negatively alter an adolescent's mood which may make them more inattentive or more inclined to seek out novel more risky situations. Given all these possible connections between sleep loss and risk-taking behavior it is imperative that we investigate this relationship further. Although previous attempts at elucidating the reason for the increase in risky behavior during the adolescent period have produced limited results, more research delving into the underlying mechanisms of this relationship will be important to inform new methods of intervention and to find a way to reduce the number of preventable deaths in this population each year.

Summary

In summary, inadequate sleep in adolescence is both chronic and prevalent. It has been established that adolescents accrue a sleep debt by the end of the week as a result of insufficient sleep throughout the week. Increased academic demands, employment, extracurricular activities, social demands, mass media as well as less parental involvement compete with adolescent sleep times. Consequently, they obtain less than optimal amounts of sleep on weeknights when commitments are most

demanding (Carskadon, 1994). This daily restriction of sleep builds up until the adolescent is significantly sleep deprived by weeks end resulting in the desire to “catch-up” by extending their sleep periods on the weekends when there are less demands on their time. This sleep debt has been linked to daytime impairments such as cognitive decrements (i.e., executive function, attention, and working memory deficits) and disturbances in mood (i.e., negative affect, diagnosable mood disorders as well as disturbances in current mood symptoms). Although less studied, results indicate increased risk-taking behavior (i.e. increased risk propensity, impulsivity, and sensation seeking) may also be associated with sleep debt. In general, causal roles among these variables are not clearly evident, however data suggests both unidirectional and bidirectional relationships may exist (see figure 1). The current study seeks to examine the relationship between sleep, working memory, current mood states, and risk-taking behavior using a unidirectional format adapted from the interactive model.

Figure 1: Interactive Model



This model incorporates many possible relationships however, only those denoted by the solid lines are pursued in the current study. The abbreviations are as follows: Exec Fx = executive function; Atten = attention; WM = working memory; NA = negative affect; DD = depressive disorders; SX = symptoms; IMP = impulsivity; SS = sensation seeking; RP = risk-taking propensity

Chapter 2: The Current Study

Although some literature exists examining working memory and current mood disturbance in adolescence under sleep debt, there is a relative paucity of information on the relationship between sleep debt and risky behavior as a whole in this population. Furthermore, evidence that does exist has been descriptive in nature and relied solely on self-report measures as opposed to including objective multimodal assessment techniques and experimental methodology. Although there are various relationships that can be explored based on the interactive model presented, the current study represents an initial step focused on the direct paths of the model, which will be useful for informing more large scale future studies to address the possible interactions that may exist.

The current study assessed 38 adolescents to determine if their level of risk-taking behavior across its various dimensions and response modes (i.e., self-report vs. behavioral tasks) was affected by sleep debt. Given that changes in current mood and working memory have been shown to be related to sleep debt, this link was examined secondarily for the purposes of replication and as a validity check in regard to the primary aims (i.e., that expected performance differences from previous work was found at the sleep debt assessment). Specifically to address these aims, self-report and behavioral assessment strategies were employed to compare within subjects differences in current mood, working memory, and risk-taking behavior on a Friday after a full week of cumulative sleep loss (i.e., sleep debt), as compared to Sunday evening after 2 nights of extended sleep (i.e., sleep recovery). Further, based on links from previous research, when necessary we controlled for age, gender, and order if

they were related to the independent variable or dependent variables. Finally, we conducted post hoc exploratory analyses examining the relationship between weekend oversleep and each dependent variable following both the sleep debt session and the sleep recovery session. We also examined the relationship between individual sleep patterns and performance following the restricted period. In addition to providing possible avenues for future research, this approach also served as a validity check to establish that adolescents did indeed sleep less prior to the sleep debt compared to the sleep recovery sessions.

Method

Participants

It was initially proposed that 48 subjects would be recruited for this study however, due to strict rule out criteria as well as study time constraints a reduced sample was obtained. The rule out criteria included a diagnosis of current clinical depression and/or suicidal ideation, as measured by a score of 19 or greater on the Child Depression Inventory (CDI; Kovacs, 1988; Smucker, Craighead, Craighead, & Green, 1986), current sleep disorders previously diagnosed, as well as sedative-hypnotic and psychostimulant medication use. In total, 38 tenth, eleventh, and twelfth grade high school students aged 16-18 were eligible. When current depression, diagnosable sleep disorders, or suicidal ideation were evident, the appropriate referral was made to ensure the safety of the adolescent. The overall sample was recruited from the Washington metropolitan area using fliers, newspaper ads, and word of mouth. Interested individuals were instructed to call the Center for Addictions,

Personality, and Emotion Research (CAPER) at the University of Maryland, College Park and an initial screener was performed at that time to see if they qualified to participate in the study. The goal was to recruit a sample that was representative of the surrounding population in race/ethnicity as well as in socioeconomic status. Additionally, both males and females were recruited equally with the goal of obtaining a gender-balanced sample.

Procedure

Once accepted into the study, participation involved three separate phases including orientation, sleep debt, and sleep recovery. The first phase, the orientation phase, included both an orientation and a short assessment battery, which lasted approximately 1 hour in duration (this session always occurred first on either a Friday or a Sunday). This session began with a brief overview of study procedures, followed by the completion of informed consent/assent, which was obtained by a trained study staff member. With regard to the assessment battery, the Wechsler Abbreviated Scale of Intelligence (WASI) was administered to each participant as well as three initial self-report measures, a measure of typical sleep habits known as the CSQ, a measure of broad psychopathology known as the Youth Self-Report (YSR), and the Child Depression Inventory (CDI), a well known measure of depressive symptoms in children. Additionally, the parents were given two measures of their own to complete simultaneously, a demographic questionnaire and the Child Behavior Checklist (CBCL) which compared individual child behaviors to that of both normal and disordered peers. Once the measures were completed, an actigraph and a sleep log

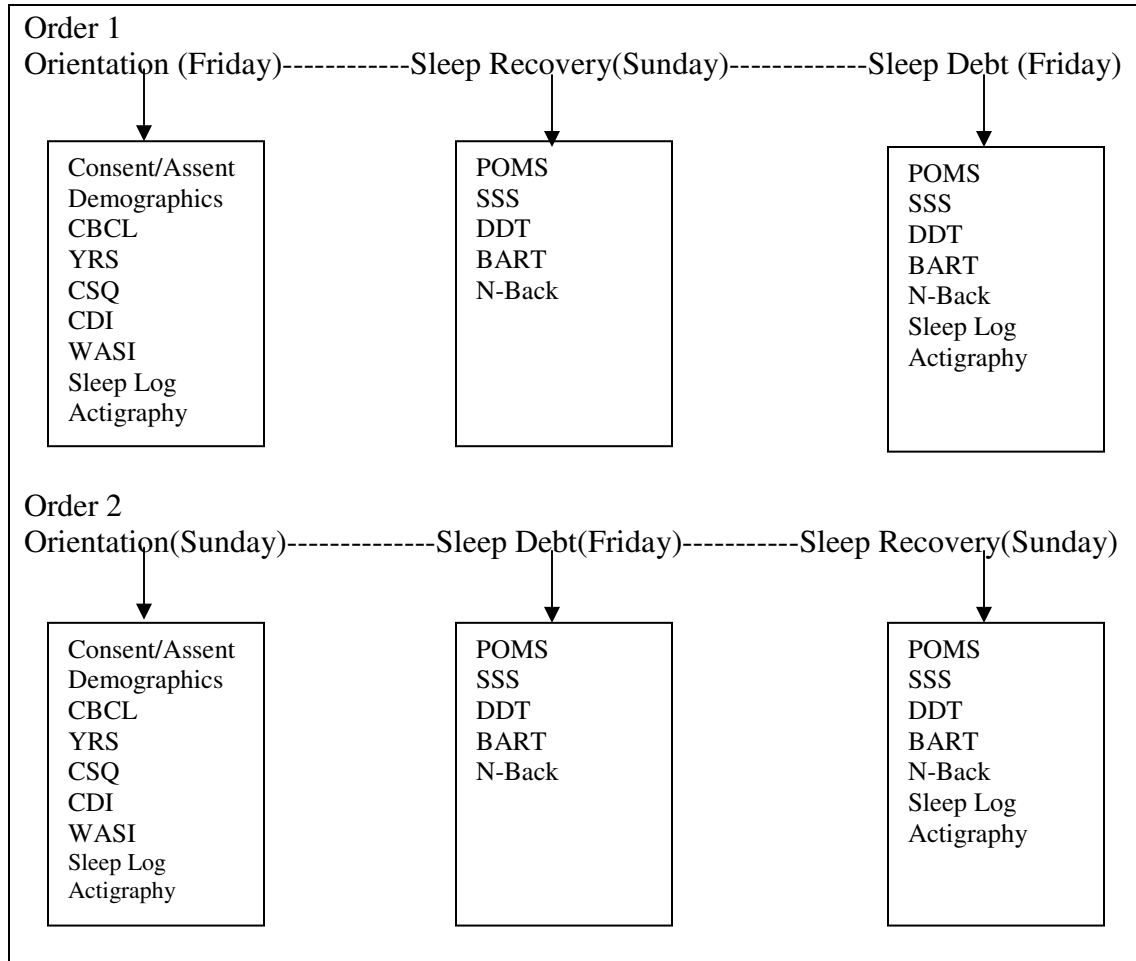
were given to each participant along with implementation instructions to monitor their sleep over a seven day period, the length of time encompassing all the nights associated with the three phases of the study (i.e., from the orientation phase to the last phase, either sleep debt or sleep recovery depending on participant entry into the study). Finally, at the end of this session adolescents were paid \$10.00 and the consenting parent was paid \$10.00 as compensation for their time and effort

The sleep debt phase either occurred as phase two or phase three, dependent upon the order the participant entered into the study. The sleep debt and recovery phases were counter balanced to account for any order effects that might occur. The sleep debt session always occurred on a Friday evening after sleep debt had accrued. During this session participants completed a battery of self-report measures and underwent 2 computerized as well as 1 paper and pencil laboratory behavioral assessment tasks. The self-report measures included two measures of disinhibition, the impulsivity subscale of the Eysenck Personality Inventory (EPI; Eysenck, Pearson, Easting, & Allsopp, 1985) and the Zuckerman Sensation Seeking Scale (SSS; Zuckerman, Eysenck, & Eysenck, 1978). Additionally, current mood was assessed using the profile of mood states (POMS; McNair, Lorr, & Droppleman, 1971). The behavioral assessment tasks that were used as outcome measures included two measures of disinhibition and one measure of working memory. Disinhibition was assessed through the Delay-Discounting Task (DDT), a paper and pencil task that measured one type of impulsivity, as well as through the BART, a computerized task that evaluated risk-taking propensity. The measure of working memory was the computerized letter n-back task. Upon completion of the assessment

battery, the following occurred based on the particular phase the participant was in. If the sleep debt session occurred as the participant's phase 2, the adolescent was given \$10.00 in addition to the prize they earned on the BART (see the assessment strategy section for further detail regarding BART prize distribution) and the parent received monetary compensation of \$10.00. If the sleep debt session occurred as phase three, then both the sleep log and the actigraph were collected after the test battery was completed and the adolescent was again given \$10.00 and compensated according to the prize they earned on the BART while the parent were compensated \$20.00. Additionally, the results of the WASI intelligence screener were given to the parent at the end of the third session.

The sleep recovery phase also occurred as either phase two or phase three dependent upon the participant's prior entry status. This session always occurred on a Sunday evening to maximize the potential of having the adolescent undergo a full recovery period. The assessment strategy, actigraphy and sleep log collection, as well as the mode of compensation were exactly the same as described in the aforementioned sleep debt session. Table 1 contains specific details of the study protocol. It also delineates the procedure based upon order of entry into the study.

Table 1: Assessment Timeline



Timeline of assessment procedures (50% of participants followed each order of entry). Abbreviations in this timeline correspond to those indicated in the assessment section.

Assessment Strategy

As previously discussed the assessment battery included a multimodal protocol incorporating both objective and subjective measures through self-report as well as through behavioral assessment. Table 2 illustrates a succinct overview of the measures, the variable they were associated with, the condition in which they were utilized, as well as the standard abbreviation used.

Table 2: Assessment Measures and Protocol

Variable	Condition	Assessment Measure	Abbreviation
Impulsivity	R/NR	Eysenck Personality Inventory	EPI
Pre-potent responding	R/NR	Commission Errors on Letter N-Back Test	N-Back
Delayed Discounting	R/NR	Kirby Delayed Discounting	DDT
Risk Propensity	R/NR	Balloon Analogue Risk Task	BART
Sensation Seeking	R/NR	Zuckerman Sensation Seeking Scale	SSS
Working Memory	R/NR	Letter N-Back Test Task	N-Back
Current Mood	R/NR	Profile of Mood States	POMS
Daily Sleep Habits	O/R or NR	Wrist Actigraphy	
Daily Sleep Habits	O/R or NR	Sleep Log	
Potential Covariate			
Intelligence Test	O	Weschler's Abbreviated Scale of Intelligence	WASI
Depression	O	Child Depression Inventory	CDI
Internalizing & Externalizing bx	O	Child Behavior Checklist	CBCL
Internalizing & Externalizing bx	O	Youth Self-Report	YSR
Demographics	O	Standard Demographic Questionnaire	
General Sleep Habits	O/R or NR	Child Sleep Questionnaire - Parent	CSQ
General Sleep Habits	O/R or NR	Child Sleep Questionnaire - Adolescent	CSQ - A

This table outlines the assessment measures and applicable protocol segment. O = orientation phase; R = restricted phase; NR = non-restricted phase.

General Measure

Demographic Questionnaire: A short self-report questionnaire was administered to obtain the grade, age, gender, and race of the child and both biological parents, highest educational level obtained by both parents, parental marital status, and household income.

Measures of Disinhibition

Eysenck Personality Inventory, impulsivity subscale (EPI; Eysenck, Pearson, Easting, & Allsopp, 1985): The impulsivity subscale of the Eysenck Personality Inventory consisted of 19 yes or no questions that gauged an individual's level of impulsivity. Higher scores indicate greater levels of impulsivity. Eysenck et al. (1985) found that the alpha coefficient was .84, for impulsiveness. Furthermore, alpha coefficients analyzed by gender were similar with males reported as .84 and females reported as .83. When used with an adolescent population Aklin, Lejuez, Zvolensky, Kahler, and Gwadz (2005) found an adequate but slightly lower alpha for internal consistency at .72. This measure was used to get an overall sense of each participant's level of impulsivity during both the sleep debt and recovery phases.

Sensation Seeking Scale (Zuckerman, Eysenck, & Eysenck, 1978): This 40-item questionnaire forces subjects to choose between two opposite statements to determine level of sensation seeking. It is available in the original long version and in revised versions such as the 8-item short form used in this study. This instrument has excellent psychometric properties (Zuckerman, 1979, 1994), with internal

consistencies shown to range from .83 to .86 (Zuckerman et al., 1978; Zuckerman, 1979) and test-retest reliability at 3 weeks was .94. In addition, evidence of construct and concurrent validity are provided by Zuckerman et al. (1978) and Zuckerman (1979, 1983, 1984). Although primarily used with adults, it has been shown to correlate with self-reported risk-taking behaviors in adolescent samples (Zuckerman et al., 1978), including those as young as 11 (Greene et al., 2000). A recent study by Aklin et al., (2005) showed adequate internal consistency in sample of 51 adolescents in 9th through 12th grades, with an alpha of .71. This measure was used to evaluate each participant's level of disinhibition as it relates to sensation seeking and was completed during both the sleep debt as well as the sleep recovery phases.

Delay Discounting Task (DDT; Kirby et al., 1999): The DDT provides a measure of the degree to which an individual shows preference for either small, immediate rewards or larger, delayed rewards, which may be stated as the rate at which the subjective value of deferred rewards decreases as a function of the delay until they are received.

The DDT, consists of a fixed set of 27 choices between smaller, immediate rewards and larger delayed rewards. For example, on the first trial, participants are asked “Would you rather have \$49 today or \$60 in 89 days?” Delays included in this questionnaire rang from 7 to 186 days. The presentation order of the delays is contrived so as not to correlate choice amounts, ratios, differences, delays, or discount rate implied by indifference to the two rewards. Previous research has shown that individual's discount curves are well described by the hyperbolic discount function (Mazur, 1987) $V = A/(1 + kD)$, in which V is the present value of the delayed reward A

at delay D , and k is a free parameter that determines the discount rate. All delays below are measured in days, and the values of k are scaled accordingly. As k increases, the person discounts the future more steeply. Therefore, k can be thought of as an *impulsiveness parameter*, with higher values corresponding to higher levels of impulsiveness.

The k values provided by the Kirby questionnaire fall within 10 discrete categories (.00016, .00025, .00063, .0016, .0039, .010, .0126, .065, .16, and .25); on the basis of their answers to the 27 items, participants will be assigned one of these k values. The k values provided by the Kirby questionnaire distinguishes between high (\$85, \$80, \$75), medium (\$60, \$55, \$50), and low (\$35, \$30, \$25) value-delayed rewards.

The DDT in its various forms (including questionnaire and computerized versions) has been widely used in research on sensation seeking, impulsivity, and risk taking and has been found to correlate with other behavioral measures of impulsivity (Monterosso, Ehrman, Napier, O'Brien, & Childress, 2001). Although primarily used with adult populations, the DDT has been used effectively with adolescent samples as well (Audrain-McGovern, Rodriguez, Tercyak, Epstein, Goldman, & Paul, 2004).

Balloon Analogue Risk Task, Adolescent Version (BART-Y; Lejuez et al., 2002): The BART has been successfully used to describe currently occurring risk behaviors in young adults (Lejuez et al., 2002) and adolescents (Aklin, Lejuez, Zvolensky, Kahler, & Gwadz, 2005; Lejuez, Aklin, Zvolensky, & Pedulla, 2003). This task has demonstrated predictive value above and beyond that provided with demographics and self-report personality measures. In two studies using adolescent populations

(Aklin, et al., 2005; Lejuez, et al., 2003), the BART was related to risk taking behaviors taken from the Youth Risk Behavior Survey produced by the CDC (r 's ranged from .30 to .50; all p 's < .05). Specifically, riskiness on the BART was related to illicit drug use in both studies and unsafe sexual practices in one of the studies. Reliability estimates have been consistently good. When broken down into the first, second and third sets of 10 balloons, no significant difference have been found between the number of pumps per set ($r = .82, p < .05$; Lejuez et al., 2003).

The adolescent version of the Balloon Analogue Risk Task (BART-Y) involves inflating a computer-generated balloon. Each pump is worth one point, but if a balloon is pumped past its explosion point, then all points accrued for that balloon are lost. The probability that any particular balloon will explode is 1/128 for the first pump, 1/127 for the second, and so on until the 128th pump at which point the probability would be 1/1. According to this algorithm, explosion values form a normal distribution around 64 pumps (see Lejuez et al., 2002 for further details). To determine the actual explosion point sequence to be used in the study, a sequence of 30 explosion points using the algorithm above was generated, repeating this approach until a sequence was generated that resulted in an average explosion point across balloons of 64 pumps. To assess split half reliability across the task, the sequence was further repeated until the first 15 balloons and the second set of 15 balloons both evidenced an explosion point of 64 pumps; because of the differing range of explosion points from balloon to balloon, and the other structural aspects of the task outlined above, other commonly used forms of reliability such as internal consistency could not be calculated in a straightforward manner. This was necessary to ensure

equivalence in the range of possible responses across balloons when comparing responding in the first half and second half of the task.

During the task, participants had the opportunity to stop pumping the balloon at any time prior to an explosion and allocate the accrued points to a permanent prize meter. After a balloon exploded or points were allocated to the permanent prize meter, a new balloon appeared. Upon completion of 30 balloon trials, the position of the prize meter determined the final prize, with markings indicating small, medium, large, and bonus prize. Participants were awarded either cash or prizes that were worth \$5.00 for the small prize, \$10.00 for the middle prize, \$15.00 for the large prize, and \$20.00 for the bonus prize. Standardized instructions were given to each participant prior to beginning the task. These instructions included the total number of balloons and the fact that points on the prize meter corresponded to specific monetary prizes awarded immediately following the task with the prize marking on the task corresponding to the monetary amount of the prize earned. Further, participants were informed that:

“It is your choice to determine how much to pump up the balloon, but be aware that at some point the balloon will explode” and that “the explosion point varies across each of the thirty balloons, ranging from the first pump to enough pumps to make the balloon fill the entire computer screen.”

Participants were not given any other information about the probability underlying the explosion point for each balloon. In line with all published BART studies to date, the average number of pumps on balloons that did not

explode was the preferred index of riskiness on the BART. This adjusted value was optimal compared to other variables such as number of explosions because it was not constrained by the explosion points across balloons.

Measure of Mood

Profile of mood states (POMS; McNair, Lorr, & Droppleman, 1971): The POMS is a self-report scale that measures current mood. It consists of 65 adjectives rated on a 5 point likert scale ranging from 0 = not at all to 4 = extremely. A total mood score as well as scores from 6 subscales can be obtained from this measure. The total mood disturbance (TMD) score, a single, global estimate of affective state, ranges from – 32 to 232, with a low score representing a more positive affective state. The six mood subscales include tension, depression, anger, vigor, fatigue, and confusion. Internal consistency for the total scale was excellent with an alpha coefficient of .95 (Bohachick et al 1992). Internal consistencies for subscales are as follows: 0.85 (anxiety) 0.88 (depression) 0.80 (confusion) 0.77 (hostility) 0.90 (fatigue) 0.88 (vigor) (Bohachick et al 1992). This measure has been primarily used with adults however, recent efforts have been made to publish an adolescent version (POMS-R: Adolescent; McNair & Heuchert). Due to the fact that the POMS-R psychometric properties are in the process of being established and no other established measure of current mood states exists for adolescents, the POMs appeared to be a reasonable choice for this study.

Measures of Psychopathology

Children's Depression Inventory (CDI; Kovacs, 1985): This measure contains 27 self-reported items that assessed depressive symptoms in children and adolescents. Items were scored using a 3-point scale of ascending depression severity. The test-retest reliability of the CDI is high for time intervals of less than 1 month (Finch, Saylor, Edwards, & McIntosh, 1987) and moderate for longer intervals (Smucker, Craighead, Craighead, & Green, 1986; Weiss et al., 1991). Concurrent validity has been demonstrated by significant correlations with other self-report measures of depression (Asarnow & Carlson, 1985; Shain, Naylor, & Alessi, 1990) as well as with clinician's ratings of depressive symptomatology (Hodges & Craighead, 1990; Shain et al., 1990).

Child Behavior Checklist & Youth Self-Report (CBCL; Achenbach, 1991; YSR; Achenbach, 1995): These measures consisted of two parts. The first contained a series of questions assessing adaptive behavior, forming three scales (i.e. activities, social competence, school competence). The second part contained 113 items describing behavior, each of which was rated using a 3-point likert scale; 0 = not true, 1 = somewhat or sometimes true, 2 = very true or often true. The CBCL was completed by the parent in reference to the adolescent and the YRS was completed by the adolescent. Each Individual's ratings were combined to form two broad scales, eight subscales, and a total problem score. The two scales are termed Internalizing and Externalizing. The eight subscales are labeled: Withdrawn, Somatic Complaints, Anxious/Depressed, Social Problems, Thought Problems, Attention Problems, Delinquent Behavior, and Aggressive Behavior. The Internalizing scale was made up

of: Withdrawn, Somatic Complaints, and Anxious/Depressed subscales. Internalizing disorders were described as emotional disturbances or behavioral deficits. The Externalizing scale was made up of the Aggressive Behavior and Delinquent Behavior scales, and was considered to reflect conduct disorders or behavioral excess. The psychometric properties for this measure have been well established for adolescent populations.

Measures of Sleep

The Child Sleep Questionnaire (CSQ): Sleep variables, were derived from a 41-item pediatric sleep questionnaire that is typically used as a clinical screen for common sleep problems in children ages 2 - 18. Generally caretakers are asked to complete the CSQ with regard to their child however since adolescents are probably better reporters of their own sleep habits at this age the adolescent participant was also asked to complete a similar questionnaire on their own behalf. Parents and adolescents responded to questions that assessed sleep habits (usual bedtime, sleep onset latency, number of awakenings and time awake after sleep onset), general questions regarding symptoms of sleep disorders (bedtime resistance, snoring, sleep walking, etc.) and an 8-item modified Epworth Sleepiness Scale (ESS) (scores range from 0 – 24) that assessed daytime sleep propensity. When answering questions, parents and adolescents were asked to report on the frequency of relevant events associated with the sleep habits, sleep schedules and the presence of common sleep disorder symptoms occurring in the past month using a 5-point Likert-type scale (anchors for scale include; 1 = never, 2 = less than once a week, 3 = 1 or two times a

week, 4 = 3 or 4 times a week, and 5 = 5 or more times a week). While participants were not formally diagnosed with sleep disorders, elevated levels of clinically significant criteria will be used to characterize the following sleep problems: behavioral sleep disorders (BSD), insomnia, excessive daytime somnolence (EDS), sleep disordered breathing (SDB), insufficient sleep, parasomnias, nightmares, and enuresis (see appendix for the complete scoring algorithm). Although psychometric properties for this measure have not yet been established, data is currently being collected with this aim.

Sleep Log: This was a self-report, daily measure of sleep, similar to a daily diary. This form covered a two week period and participants were asked to record their exact sleep and wake times by shading in boxes that correspond with the time of day. Each box represented a period of one hour and could be shaded in part or whole to denote complete hours or fractions thereof. Sleep logs were given to each participant during the orientation phase and they were instructed to complete the logs as accurately as possible until they return for their last session, one week later. The participants were told that the logs must be completed on a daily basis following each wake-up period. In addition, they were explicitly told that the sleep logs that they complete will be verified with the wrist actigraphs in accordance with the findings of Carney, Lajos, and Waters (2004) that revealed that participants had better compliance rates when they were aware of the purpose of the actigraphic monitor. For purposes of this study, participants only monitored their sleep for a one-week period spanning from orientation to the last day of the final phase (i.e. sleep debt or sleep recovery dependent upon entry into the study). Although this was considered a

subjective form of measuring daily sleep habits it has been shown to be as reliable as polysomnography when used in conjunction with actigraphic data (Sadeh & Acebo, 2002).

Wrist Actigraphy: The Ambulatory Monitoring Octagonal Basic Motion Logger was used to estimate the timing of sleep wake periods. This device records data in epochs of one second, two seconds, 10 seconds, 60 seconds, and greater. Sixty-second epochs have been the standard time frame employed for sleep scoring with this model. The actigraph is a wristwatch like device that records daily activity with motion sensors. Computer algorithms have been developed to score probable sleep and wake periods. Actigraphy has been shown to provide a reliable and valid objective measure of activity and rest periods during the day and night (Morgenthaler et al., 2007). The Sadeh Algorithms were used to compare the daily recorded movements to normative data that has been shown to be a reliable measure of sleep and wake periods. Research has shown a combination of daily sleep logs and wrist actigraphy are as reliable indicators of daily sleep as polysomnography (Sadeh & Acebo, 2002). However, whereas PSG only provides a lab based measure, actigraphy provides a longitudinal naturalistic measure of sleep. Participants monitored their sleep using the actigraphs for a period of 7 days, which corresponded with optimal monitoring duration for adolescents as indicated by Acebo and colleagues (1999). They were given the device during the orientation phase and instructed to wear it constantly throughout the day until they return for their last session in one week. The subjects was directed not to take off the actigraph unless absolutely necessary and provided a written record of instances when the device was removed as well as the

reason for removal. As no differences have been found regarding wearing the system on either the dominant or non-dominant wrist, participants were instructed to wear the monitor on their non-dominant hand to reduce daily wear and tear.

Test of Intelligence

Wechsler Abbreviated Scale of Intelligence (WASI; Weschler, 1999): The WASI, two subtest form, consisted of Vocabulary and Matrix Reasoning. The vocabulary subtest utilized 4 picture items and 38 word items of which the subject was asked to define in detail. Matrix reasoning was made up of four types of nonverbal reasoning items: pattern completion, classification, analogy, and serial reasoning where the subject was asked to complete a portion of the incomplete item. Adequate reliability of each subtest has been shown (reliability coefficients range from .81 to .97 in children) and content, construct, as well as clinical validity has been demonstrated for this measure of intelligence (Kaufman, A. S., & Lichtenberger, E. O., 1999; Psychological Corp., 1999).

Test of Cognitive Function

Letter n-Back test (Braver et al., 1997): The letter *n*-back test is a task that focused on working memory and gave secondary information on impulsivity via commission errors committed by the participant. Sequences of consonants in capital letter form with stimulus duration of 500 ms and an inter-stimulus interval of 2,500 ms were displayed on the computer screen. In the 0-back condition, participants responded to a single specified target. During the 1-back condition, participants responded if the

target consonant is identical to the letter preceding it. In the 2-back condition, participants were required to respond if the letter was identical to the one presented two trials back. There were 15 letters presented for each condition, and each condition was repeated three times in pseudorandom order for a total of 135 stimuli. There was a 9-s delay at the start of the task and between conditions, during which an instruction screen appeared informing the participant of the upcoming condition. Adequate validity and test/re-test reliability have been shown for this task under all three conditions (Braver et al., 1997; Hockey & Geffen, 2004; Raglend et al., 2002). This task has been successfully used to differentiate spatial working memory in normal controls as compared with autistic children, adolescents, and adults (Williams, Goldstein, Carpenter, & Minshew, 2005).

Data Analysis Plan

First, descriptive statistics for demographic variables, WASI, and CDI were calculated. Then correlations between measures of daily sleep as well as between Epworth scores and sleep log data using Pearson's r were calculated in order to establish the reliability of these measures. Next, correlational analyses were conducted using demographics and the primary outcome measures to determine which if any covariates would be used in subsequent analyses. Then the differences between weekday and weekend total sleep time across phases were examined using t -tests. Assuming significant findings for the weekday/weekend total sleep time, we planned to test the within subject differences on measures of working memory, current mood, and disinhibition from phase one to phase two using repeated measures ANOVA or ANCOVA as necessary. Finally exploratory analyses were planned to investigate the relationship of additional sleep parameters to measures of daily functioning using t -tests, Chi-square, partial correlations and regression analyses as appropriate. Specifically, t -tests and chi-squares were utilized to investigate whether there were differences between discrepancy groups with regard to demographic variables. Partial correlations were used to determine if a relationship existed between weekday total sleep and measures of problem behavior as well as IQ. Finally regression analyses were used to ascertain 1) whether weekend oversleep (i.e. the discrepancy between weekend and weekday total sleep time) was predictive of performance following both phases, 2) whether the standard deviation of individual total weekday sleep time was predictive of performance following the restricted

phase, as well as 3) whether Thursday night sleep debt was predictive of the same primary variables following the restricted time period.

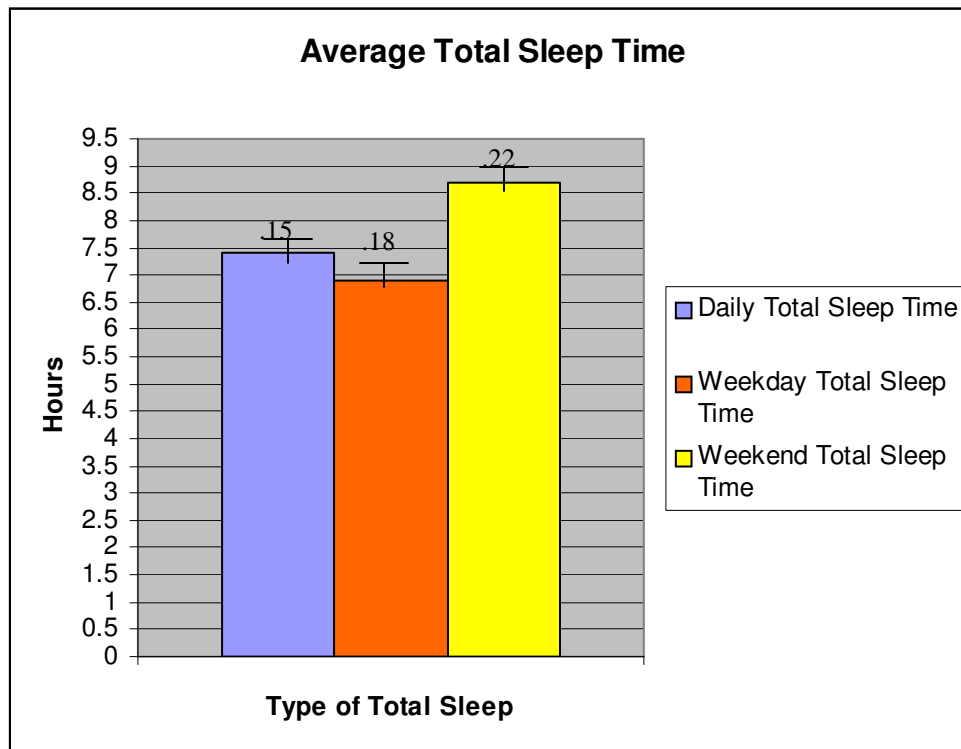
Chapter 3: Results

Subjects

After qualification through the initial screening process, a total of 38 of the proposed 48 subjects participated in this study. Of the 38, one subject was disqualified due to noncompliance and 2 subjects were disqualified due to an irregular daily schedule (i.e. spring break). Two of the three dropped participants were Caucasian with the other being African American, two were female, and two underwent the recovery phase first. The average age of the dropped subjects was 15.6 years old. Sleep characteristics of the two that complied with the protocol were as follows: average daily total sleep time = 7.84 hrs, average weekday total sleep time = 8.73 hrs, and average weekend total sleep time = 5.63 hrs. Of the 35 remaining participants, the total sample population was primarily African American (54%) and male (51%) with a mean age of 16 ($SD = .89$). The order of participation was relatively equal with 51% ($n = 18$) starting with the restricted phase first and 48% ($n = 17$) starting with the recovery phase. With regard to sleep characteristics, the mean daily total sleep time was 7.41hrs ($SD = 9.1$), the mean weekday total sleep time was 6.92 hrs ($SD = 1.05$), and the mean weekend total sleep time was 8.65 hrs ($SD = 1.33$; see graph 1). There were 2 participants that could be classified as short sleepers (i.e. total daily sleep duration of <6 hours) however, 10 individuals met criteria for short

sleep duration during the weekday. With regard to long sleepers, two participants slept an average of 9 hours or more throughout the week and 14 slept an average of 9 hours or greater over the weekend time period.

Graph 1: Average Total Sleep Time In The Three Primary Domains



Preliminary Analyses

Measures of Sleep. Actigraphy and sleep logs were used to provide objective and subjective measures of daily sleep and wake periods. Three indices of total sleep were used including average daily total sleep, average weekday total sleep, and average weekend total sleep. Table 3 shows the correlations between sleep log and actigraphy data when average daily sleep, average weekday sleep, and average weekend sleep

were analyzed. Results indicate that actigraphy and sleep log measurements show a positive correlation for all three indices (average daily, $p = .024$; average weekday, $p = .002$; average weekend, $p = .000$). A further examination of means, shows that the sleep log and actigraphy weekday total sleep time differed on average by 12 minutes, however, sleep logs overestimated the total sleep time on the weekend and underestimated the daily total sleep time as compared to actigraphy in this sample (see table 3). Given these similarities in measurement, unless otherwise stated, the data from the sleep logs were used as the primary measures of sleep for the remainder of the analyses to maximize sample size.

Data on habitual sleeping patterns were also obtained through both parental and adolescent report on the CSQ. Scores on this measure highlighted elevated symptom expression of disordered sleep in 14 participants by parent and/or adolescent report and of those 14, six had elevations in multiple diagnostic categories. In total, 8 had elevated symptoms of excessive daytime somnolence, 7 for delayed sleep phase syndrome, 5 for insufficient sleep syndrome, 2 for insomnia, one for nightmares, and one for sleep disordered breathing (see table 4). Each of these participants were informed of their status and referred for follow-up to a pediatric behavioral sleep medicine specialist as needed. Descriptive statistics on these fourteen individuals show an average age of 16.4 ($SD = 1.03$), equal numbers of males and females, 57% African American, and 64% entered the study through the restricted phase first. There were higher problem behavior scores on the YRS as compared to the CBCL with elevated scores on the externalizing subscale (56.79, $SD = 11.09$ and 49.89, $SD = 11.45$ respectively), the internalizing subscale (55.57, $SD =$

9.84 and 52.64, $SD = 8.9$ respectively), and the total problems scale (57.07, $SD = 10.16$ and 51.93, $SD = 10.56$ respectively). Higher parental report of excessive daytime somnolence was revealed although neither adolescent nor parental report reached clinical threshold (i.e., >10). Additionally an average CDI score of approximately 7.36 ($SD = 4.56$) and an average IQ score of approximately 111.29 ($SD = 11.84$) were shown for these 14 individuals. With regard to sleep, their average total daily sleep was 7.19 hours ($SD = .96$), their average total weekday sleep was 6.69 hours ($SD = 1.13$), and their average total weekend sleep was 8.42 hours ($SD = 1.24$). Additionally, Epworth scores were calculated for the entire sample and correlational analyses were conducted to determine if a relationship existed between habitual daytime somnolence and current measures of weekday and weekend total sleep time. As expected, results indicated that parent report of habitual daytime somnolence was negatively correlated with the amount of sleep individuals received during the week ($p = .004$; see table 5). This suggests that the less daily total sleep that an adolescent receives the more signs of daytime sleepiness they exhibit.

When looking at the sample as a whole, the average amount of sleep obtained over the course of a full 7-day week ($M = 7.6$, $SD = .90$) was within the range of previous findings (Chung & Cheung, 2008; Lazaratou et al., 2005; Liu et al., 2000; Wolfson & Carskadon, 1998). In addition, the predicted pattern of restricted sleep during the weekdays and extended sleep on the weekends was also evidence by the current sample, as a significant difference was found between the two periods (see figure 2 and table 6). Next correlational analyses were conducted using order, gender, age, race and the primary outcome measures (i.e. BART, n-Back, POMS,

DDT, EPI, & SSS) to determine if any covariates should be utilized for subsequent analyses. Results indicated a significant relationship between order and BART total ($r = -.34, p < .05$), between gender and POMs total ($r = -.34, p < .05$), and between age and delay discounting medium ($r = .39, p < .05$) following the restricted phase (see table 7). Similar results were found for the recovery phase with the exception of the relationship between age and delay discounting medium. Given these significant findings it was decided to control for age, gender, and order when appropriate. Next, within the typical pattern of adolescent sleep, partial correlational analyses were conducted to examine the relationship between restricted sleep and problem behaviors while controlling for gender, age, and order. Results indicated that weekday sleep duration was significantly associated with problem behaviors as measured by the total problem scales of the CBCL and approached significance with the YSR (see table 8). Specifically, Monday, Tuesday, and Thursday night total sleep time was significantly correlated with the total problem scale based on parent report (Monday, $r = -.41, p < .05$; Tuesday, $r = -.45, p < .05$; Thursday, $r = -.42, p < .05$). When looking at youth self-report, only Sunday night total sleep time was significantly correlated with the total problem scale (Sunday, $r = -.35, p = .05$). In an effort to check for overall covariates, analyses were also run to determine if demographic and sleep variables differed based on the order in which they entered the study (i.e., restricted phase first vs. recovery phase first). No significant differences were found (see table 9).

Measures of General Behavior. In addition to the preliminary analyses conducted using the measures of sleep a second wave of analyses were conducted to examine the

associations between general problem behavior, as measured by both the CBCL and YSR, and the primary outcome measures of the study. Results showed that during the restricted phase impulsivity was positively correlated with externalizing and total problem scores on both measures (CBCL externalizing $r = .54$, $p < .001$; YSR externalizing $r = .75$, $p < .001$; CBCL total problems $r = .46$, $p < .01$; YSR total problems $r = .70$, $p < .001$). Sensation seeking negatively correlated with both measures for externalizing problems (CBCL externalizing $r = -.48$, $p < .01$; YSR externalizing $r = -.64$, $p < .001$) however it was only correlated with the YSR for total problem behaviors (YSR total problems $r = -.56$, $p < .001$). Furthermore, YSR was found to negatively correlate with delay discounting small value rewards (YSR internalizing $r = -.40$, $p < .05$) as well as current mood (YSR total problems $r = .38$, $p < .05$). No other associations were found with other dependent measures or internalizing scores for this phase of the study. During the recovery phase, sensation seeking (CBCL externalizing $r = -.48$, $p < .01$; YSR externalizing $r = -.61$, $p < .001$; YSR internalizing $r = -.42$, $p < .05$; YSR total problems $r = -.56$, $p < .001$), impulsivity (CBCL externalizing $r = .54$, $p < .001$; YSR externalizing $r = .71$, $p < .001$; YSR internalizing $r = .55$, $p < .001$; CBCL total problems $r = .39$, $p < .05$; YSR total problems $r = .70$, $p < .001$), accuracy (CBCL externalizing $r = .45$, $p < .05$; YSR externalizing $r = .46$, $p < .01$; CBCL total problems $r = .40$, $p < .05$; YSR total problems $r = .38$, $p < .05$), and omission errors (CBCL externalizing $r = -.44$, $p < .05$; YSR externalizing $r = -.46$, $p < .01$; CBCL total problems $r = -.39$, $p < .04$; YSR total problems $r = -.38$, $p < .05$) were correlated with various externalizing, internalizing, and total problem behavior scales. In addition, current mood was correlated with

total problem behavior (YSR total problems $r = .36$, $p < .05$). No other associations were found with other dependent measures.

Table 3: Means, Standard Deviations, And Correlations Of Sleep Measures In Minutes.

Measure		M	SD	1	Measure				
					2	3	4	5	6
1)	Sleep Log Total	450.24	54.27	1	.881*	.516*	.441*	.341	.268
2)	Sleep Log Weekday	426.00	65.43		1	.050	.418*	.854*	-.051
3)	Sleep Log Weekend	511.20	90.23			1	.147	-.361	
4)	Actigraphy Log Total	466.52	61.89				1	.641**	
5)	Actigraphy Weekday	438.12	61.93					1	-.008
6)	Actigraphy Weekend	500.98	96.72						1

* $p < .05$. ** $p < .001$; Total = average sleep for the entire week; Weekday, = average sleep from Sunday through Thursday nights; Weekend = average sleep on Friday and Saturday nights.

Table 4: Means And Standard Deviations For Basic Sleep Characteristics.

Variable	N	Mean	SD
Average Daily TST (hrs)	35	7.41	9.1
Average Weekday TST (hrs)	35	6.92	1.05
Average Weekend TST (hrs)	35	8.65	1.33
Bedtime			
Average Weekday	35	11:44pm	1hr
11mins			
Average Weekend	35	12:41am	1hr
22mins			
Wake time	35		
Average Weekday	35	6:33am	48mins
Average Weekend	35	9:09am	1hr
29mins			
Epworth Scores	35		
Parent report		8.11	3.70
Adolescent Report		8.09	4.37
*Elevated Sleep Sx	15		
EDS	8		
DSPS	7		
ISS	5		
Insomnia	2		
Nightmares	1		
SDB	1		

* Several subjects indicated elevated symptom levels in multiple categories; TST = total sleep time, Daily Sunday –Saturday, Weekday = Sunday-Thursday, Weekend = Friday & Saturday, EDS = Excessive Daytime Somnolence, DSPS = Delayed Sleep Phase Syndrome, ISS = Insufficient Sleep Syndrome, SDB = Sleep Disordered Breathing. Criteria for the elevated sleep symptoms can be found in the appendix.

Table 5: Means, Standard Deviations, And Correlations Of Epworth Scores And Total Sleep Time.

Measure	M	SD	Measure			
			1	2	3	4
1)Epworth (p)	8.11	3.70	1	.611**	-.173	-.477**
2)Epworth (a)	8.09	4.37		1	-.033	.225
3)Wknd TST	8.65	1.33			1	.225
4)Wkdy TST	6.92	1.05				1

**p < .001; Epworth (p) = Epworth parent report, Epworth (s) = Epworth adolescent report, Wkdy TST = weekday total sleep time; Wknd TST= weekend total sleep time.

Figure 2: Sleep Across The Week

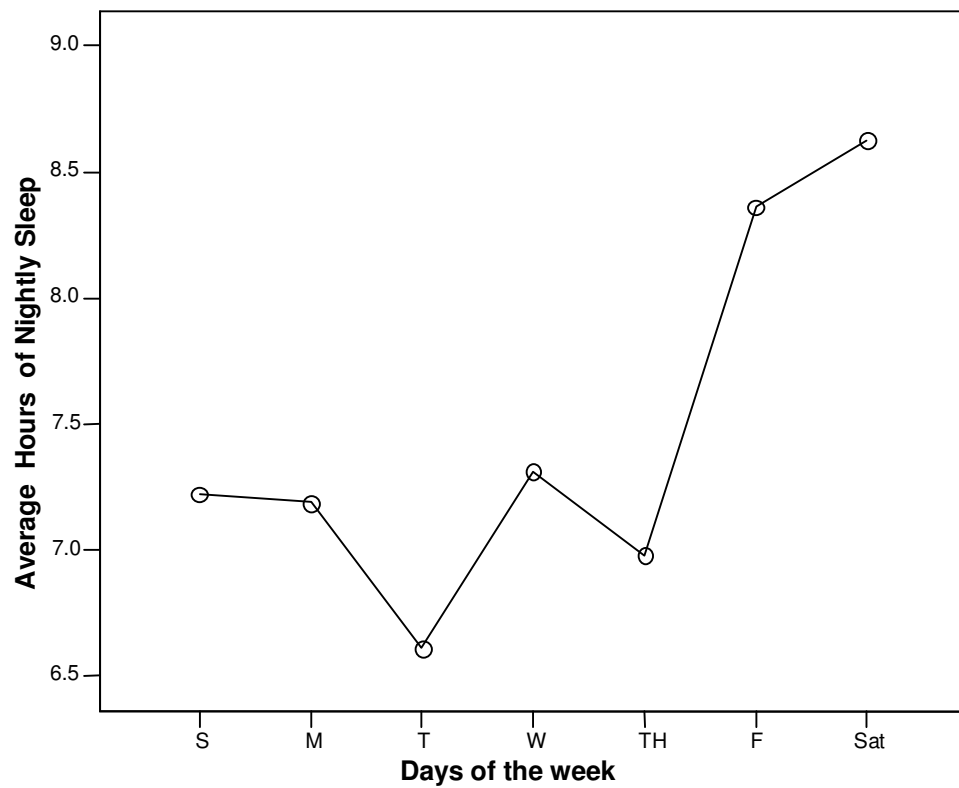


Table 6: Paired Samples T-Test Results For Average Nightly Sleep Across Phases.

Variable	Weekday		Weekend		t
	N = 35		N = 35		
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	
Average nightly sleep 6.71**	7.01	1.05	8.69	1.36	-

**p < .001

Table 7: Means, Standard Deviations, And Correlations Of Demographics And Measures Of Disinhibition & Mood Following The Restricted Phase.

Measure	M	SD	Measure										
			1	2	3	4	5	6	7	8	9	10	11
1) Order	.49	.51	1	-.09	-.10	.28	.23	-.20	-.01	.01	.04	.13	-.34*
2) Gender	.51	.51		1	.36*	.01	-.15	-.34*	.04	.16	.12	.19	.06
3) Age	15.97	.89			1	-.18	-.21	-.10	-.22	.28	.34*	.19	.17
4) Race	1.71	.79				1	.05	-.13	.20	.16	.01	.21	-.34
5) SS Tot	21.31	5.70					1	-.10	-.69**	.14	-.09	.03	.05
6) POMS tot	59.63	23.12						1	.21	-.18	-.18	-.19	.16
7) EPI Tot	8.03	3.54							1	-.16	-.25	-.18	-.13
8) DDS	.04	.09								1	.63**	.60**	.52**
9) DDM	.08	.07									1	.66**	-.32
10) DDL	.15	.08										1	-.53**
11) BART tot	35.79	12.63											1

*p < .05. **p < .01; red denotes correlations of interest; SS tot = Sensation Seeking total score; POMS tot = Profile of Mood States total score; EPI tot = Eysenk Personality Inventory tot; DDS = Delay discounting small; DDM = Delay discounting medium; DDL = Delay discounting large; BART tot = Balloon analogue risk-taking task total score.

Table 8: Means, Standard Deviations, And Partial Correlations Of Weekday Total Sleep Time And Measures Of Behavior Problems, Depressed Mood, As Well As IQ, While Controlling For Age, Gender, And Order.

Measure	M	SD	Measure				
			1	2	3	4	5
1) Wkdy TST	6.92	1.05	1	-.50**	-.34	-.23	-.20
2) CBCL tot	48.34	10.90		1	.61**	.62**	.17
3) YRS tot	53.43	4.99			1	.78**	.34
4) CDI Tot	7.34	1.33				1	.36*
5) WASI IQ tot	110.26	10.23					1

*p < .05; **p < .01; p = .06; Wkdy TST = weekday total sleep time; CBCL tot = child behavior checklist total score; YRS tot = youth self report total score; CDI Tot = total score from the children's depression inventory; WASI IQ = Weschler's abbreviated scale of intelligence total IQ score.

Table 9: T-test and Chi Square Results For Demographic, IQ, Depression, And Sleep Variables In Relation To Order Of Participation In The Study.

Variable	Restricted <i>n</i> = 18	Recovery <i>n</i> = 17	X ²
Gender	<i>M</i> = 10, <i>F</i> = 8	<i>M</i> = 8, <i>F</i> = 9	.740
Race/Ethnicity			.366
African American	<i>n</i> = 9	<i>n</i> = 10	
Asian	<i>n</i> = 0	<i>n</i> = 1	
Caucasian	<i>n</i> = 9	<i>n</i> = 5	
Hispanic	<i>n</i> = 0	<i>n</i> = 1	
	Mean(<i>SD</i>)	Mean(<i>SD</i>)	<i>t</i>
Age	16.06 (.94)	15.88 (.86)	.569
WASI IQ	112.00 (10.62)	108.41 (9.77)	1.04
CDI	6.67 (4.70)	8.06 (5.32)	.821
Income	6140.71 (3760.84)	5845.12 (2173.20)	.281
Average Daily Sleep	7.56 (.89)	7.2 (.98)	.405
Average Weekday Sleep	7.07 (.99)	6.94 (1.13)	.374
Average Weekend Sleep	8.73 (1.56)	8.64 (1.16)	.192

WASI IQ = Weschler Abbreviated Scale of Intelligence total score; CDI, Children's Depression Inventory.

Relationship Between Sleep Debt and Measures of Disinhibition

Overall no significant differences were found on measures of disinhibition when compared across phases. A repeated measures ANCOVA using order, gender, and age as covariates, revealed that performance on the BART, DDT, SSS, and the EPI

did not significantly differ between the sleep restricted phase and the recovery phase (see table 10).

Table 10: Means, Standard Deviations, And Repeated Measures ANCOVA For Effects Of Phase On Measures Of Disinhibition.

Variable	<u>Weekday</u>		<u>Weekend</u>		<u>ANCOVA</u>	
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>F</u> (1,34)	<u>p</u>
BART	35.79	12.63	36.82	15.04	.17	.68
EPI	8.06	3.54	8.26	3.35	.02	.90
SSS	21.31	5.70	21.74	5.67	.36	.56
DD (small)	.04	.09	.02	.07	.26	.61
DD (Med)	.08	.07	.08	.07	.17	.68
DD (Large)	.15	.08	.15	.07	.97	.33

BART refers to the Balloon Analogue Risk Task; EPI, Eysenck Personality Inventory; SSS, Sensation Seeking Scale; DD(Small) Delay Discounting Task small value; DD(Med) Delay Discounting Task medium value; DD(Large) Delay Discounting Task large value;

Relationship Between Sleep Debt and Measures of Working Memory and Mood

Similar to measures of disinhibition, most measures of working memory and current mood were also found to be comparable across phases. However, a repeated measures ANCOVA using the same covariates previously discussed showed significant differences in reaction time between the restricted and recovery phases on the letter N-back task ($F(1,30) = 3.50, p = .02$). No other cognitive or mood variables were statistically significant (i.e. accuracy, commission errors and omission errors; see table 11). This finding is different from previous research examining

cognitive function and mood during sleep deprivation and sleep restriction periods.

These inconsistent results are examined further in the discussion section

Table 11: Means, Standard Deviations, And Repeated Measures ANCOVA For Effects Of Phase On Measures Of Working Memory & Current Mood Controlling For Order, Gender, And Age.

Variable	<u>Weekday</u>		<u>Weekend</u>		<u>ANCOVA</u>	
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>F</u> (1,30)	<u>p</u>
POMS	61.32	23.41	60.97	24.04	.24.	.63
N-Back (RT)	428.87	48.68	419.62	38.48	5.98	.02*
N-Back (AC)	86.73	9.05	84.72	11.99	.46	.50
N-Back (C)	1.52	1.26	1.71	2.04	.98	.33
N-Back (O)	5.03	3.51	5.77	4.51	.58	.45

*P< .05; POMS refers to Profile of Mood States scale; N-Back (RT) , letter N-Back task measure of reaction time; N-Back (AC), Letter N-Back task measure of accuracy; N-Back (C), Letter N-Back measure of commission errors; N-Back (O), Letter N-Back task measure of omission errors

Variability in Individual Sleeping Patterns

Despite the fact that only one within subject difference was found in the sample from the restricted phase to the recovery phase it is still important to acknowledge that individual differences may exist with regard to accrued sleep debt across the course of the week and an individual's ability to cope with the effects of decreased sleep. Therefore, individual differences between subjects' total sleep time during the week and the amount of sleep obtained on the weekend compared to the weekday as they pertain to weekday impairment were examined.

Discrepancy in Sleep Patterns from Weekday to Weekend

Previous literature focusing on weekend oversleep, bedtime delay, and delayed sleep phase have shown decrements in daytime function using weekday/weekend discrepancy data that range from 60 minutes to ≥ 2 hrs (Carskadon & Wolfson, 1998; Lack, 1986; O'Brian & Mindell, 2005). Based on that research and the results of a median split, this sample was divided into two groups, those that obtained ≥ 1.5 hours more sleep on the weekend compared to the weekday and those that obtained < 1.5 hours difference. We used a conservative cut off score of 1.5 hours in an effort to provide the best opportunity to investigate this parameter with relatively adequate sample size and power. The low discrepancy group consisted of 17 subjects (M age = 15.88, $SD = .86$) with 7 participants who entered the study during the restricted phase and 10 during the recovery. There were 9 males and an even split between Caucasian and African-American participants with 8 subjects from each category. The high discrepancy group had 18 subjects (M age = 16.06, $SD = .94$), 11 of whom started with the restricted phase of the study first. There were 8 males and 11 African American participants with the remainder of Caucasian descent. T-tests and chi-square analyses found no significant group differences on demographic variables. Similarly, average daily total sleep was not significantly different between groups, however the groups did differ on average weekday total sleep time (M low discrepancy = 7.46, M high discrepancy = 6.40; $F(2,33) = 2.23$, $p < .01$) as well as average weekend total sleep time as expected (M low discrepancy = 7.94, M high discrepancy = 9.32; $F(2,33) = .51$, $p < .01$; see table 12).

Next we examined variables as a function of discrepancy separately for both the debt and recovery phases. To determine if a relationship existed between the discrepancy groups on measures of disinhibition during the restricted phase, ANOVA analyses were conducted using the BART, EPI, SSS, DDT, and N-Back commission errors as dependent variables. Results showed that significant differences existed between the discrepancy groups and their performance on the BART (M low discrepancy = 30.91, M high discrepancy = 40.40; $F(1, 34) = 5.60$, $p < .05$) as well as in the number of commission errors committed on the N-back task (M low discrepancy = 2.12, M high discrepancy = 1.07; $F(1, 31) = 5.21$, $p < .05$) (see table 13 & 15). All other variables were not statistically significant. To further delineate the nature of these significant findings, linear regression analyses were conducted to determine if level of discrepancy was predictive of BART scores and letter n-back commission errors during the restricted phase. Results indicated that level of discrepancy was indeed predictive of BART scores and commission errors approached significance, with the former accounting for 14.5% of the variance above and beyond what order, gender, or age contributed (see tables 14a-c). Further, given that externalizing behaviors have been associated with BART in previous studies, regression analyses were conducted to determine whether externalizing behaviors by either adolescent or parent report were significantly predictive of the level of discrepancy while controlling for order, gender, and age. The results revealed that externalizing scores on the CBCL were predictive of discrepancy group membership, accounting for 11% of the variance above and beyond what the covariates contributed ($p = .05$, R^2 change = .11). When current mood and cognitive function were assessed

during the same phase between the two groups no significant differences were found (see table 15).

During the recovery phase the same variables of disinhibition, current mood, and cognitive function were examined between groups and no statistically significant results were found (see tables 16 & 17). However, the BART approached significance during this time period ($p = .053$) with a rather respectable effect size ($\eta^2 = .11$).

Table 12: T-Test And Chi Square Results For Demographic, IQ, Depression, And Sleep Variables In Relation To Level Of Discrepancy.

Variable	Low Discrepancy <i>n</i> = 17		High Discrepancy <i>n</i> = 18		F
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	
Age	15.88	.86	16.06	.94	.39
WASI IQ	107.41	9.81	112.94	10.15	.75
CDI	6.35	4.33	8.28	5.50	.47
Income	6116.68	5683.38	6268.06	3743.63	4.18
Average Daily Sleep	7.59	.79	7.24	1.00	.10
Average Weekday Sleep	7.46	.82	6.40	.99	.15**
Average Weekend Sleep	7.94	1.09	9.32	1.19	.48**
	Low Discrepancy <i>n</i> = 17		High Discrepancy <i>n</i> = 18		X ²
Order					.20
Restricted	7		11		
Recovery	10		7		
Gender	M = 9, F = 8		M = 9, F = 9		.57
Race/Ethnicity					.44
African American	<i>n</i> = 8		<i>n</i> = 11		
Asian	<i>n</i> = 0		<i>n</i> = 1		
Caucasian	<i>n</i> = 8		<i>n</i> = 6		
Hispanic	<i>n</i> = 1		<i>n</i> = 0		

***p* < .01; WASI = Weschler Abbreviated Scale of Intelligence; CDI = Children's Depression Inventory.

Table 13: ANOVA Results For Measures Of Disinhibition During The Restricted Phase.

Variable	Low Discrepancy <i>n</i> = 17 Mean (<i>SD</i>)	High Discrepancy <i>n</i> = 18 Mean (<i>SD</i>)	F
BART	30.29 (10.69)	41.35 (11.95)	5.60*
EPI	8.71(3.44)	7.39(3.61)	1.22
SSS	20.53 (5.79)	22.06(5.67)	.620
DD (small)	.05(.09)	.03(.08)	.50
DD (Med)	.09(.08)	.07(.07)	.52
DD (Large)	.16(.07)	.14(.08)	.39

**p* < .05; BART, Balloon Analogue Risk Task; EPI, Eysenck Personality Inventory; SSS, Sensation Seeking Scale; DD(Small) Delay Discounting Task small value; DD(Med) Delay Discounting Task medium value; DD(Large) Delay Discounting Task large value; N-Back

Table 14a: Means and Standard Deviations For Restricted BART Score, Letter N-Back Commission Errors, And Covariates (i.e. Order, Gender, & Age).

Variable	N	Mean	SD
Bart total	35	35.79	12.63
N-Back (CO)	32	1.63	1.39
Discrepancy Score	35	.47	.51
Age	35	1.71	.79
Order	35	.49	.51
Gender	35	.51	.51

N-Back (CO), Letter N-Back measure of commission errors.

Table 14b: Linear Regression Analyses To Determine Whether Level Of Discrepancy Predicts Performance On Restricted BART Above And Beyond The Contributions Of Gender, Age, and Order.

Step	Predictor Variable	R ²	ΔR ²	ΔF
1	Covariates	.18	.18	2.23
2	Discrepancy Score	.20	.12	4.89*

* p< .05; Dependent variable: BART total score

Table 14c: Linear Regression Analyses To Determine Whether Level Of Discrepancy Predicts Performance On The Restricted N-Back With Regard To Commission Errors Above And Beyond The Contributions Of Gender, Age, And Order.

Step	Predictor Variable	R ²	ΔR ²	ΔF
1	Covariates	.09	.09	.96
2	Discrepancy Score	.21	.11	3.78

p = .06; Dependent variable: N-Back commission errors

Table 15: ANOVA Results For Measures Of Working Memory & Current Mood During The Restricted Phase.

Variable	Low Discrepancy <i>n</i> = 17 Mean (<i>SD</i>)	High Discrepancy <i>n</i> = 18 Mean (<i>SD</i>)	F
POMS	55.88(20.45)	63.17 (25.47)	.86
N-Back (RT)	424.60(48.28)	430.38(50.66)	.11
N-Back (AC)	84.77 (9.58)	88.59(8.03)	1.47
N-Back (O)	5.55(3.62)	4.07(3.08)	1.37
N-Back (CO)	2.12(1.50)	1.07(1.03)	5.21*

*p< .05; POMS refers to Profile of Mood States scale; N-Back (RT) , letter N-Back task measure of reaction time; N-Back (AC), Letter N-Back task measure of accuracy; N-Back (O), Letter N-Back task measure of omission errors; N-Back (CO), Letter N-Back task measure of commission errors

Table 16: ANOVA Results For Measures Of Disinhibition During The Recovery Phase.

Variable	Low Discrepancy <i>n</i> = 17 Mean (<i>SD</i>)	High Discrepancy <i>n</i> = 18 Mean (<i>SD</i>)	F
BART	31.79 (13.73)	41.56 (15.03)	4.02
EPI	8.76(3.53)	7.78(3.19)	.76
SSS	20.94 (6.22)	22.50(5.16)	.65
DD (small)	.02(.06)	.03(.08)	.28
DD (Med)	.08(.07)	.07(.07)	.04
DD (Large)	.14(.08)	.15(.07)	.00

P = .053; BART, Balloon Analogue Risk Task; EPI, Eysenck Personality Inventory; SSS, Sensation Seeking Scale; DD(Small) Delay Discounting Task small value; DD(Med) Delay Discounting Task medium value; DD(Large) Delay Discounting Task large value; N-Back

Table 17: ANOVA Results For Measures Of Working Memory & Current Mood During The Recovery Phase.

Variable	Low Discrepancy <i>n</i> = 17 Mean (<i>SD</i>)	High Discrepancy <i>n</i> = 18 Mean (<i>SD</i>)	F
POMS	56.12(17.85)	61.44 (27.93)	.45
N-Back (RT)	426.62(32.92)	412.72(42.12)	1.08
N-Back (AC)	82.26 (14.64)	87.12(7.79)	1.37
N-Back (O)	6.69(5.47)	4.88(3.01)	1.35
N-Back (CO)	2.19(2.20)	1.38(1.83)	1.28

POMS refers to Profile of Mood States scale; N-Back (RT) , letter N-Back task measure of reaction time; N-Back (AC), Letter N-Back task measure of accuracy; N-Back (O), Letter N-Back task measure of omission errors; N-Back (CO), Letter N-Back task measure of commission errors

Variability in Weekday Sleeping Patterns as They Relate to Performance on Friday

Considerable variability is likely to exist between subjects on the amount of sleep they obtain on a day-to-day basis. Although their total daily sleep time may average out as a whole it is possible that the subjects obtained that average in a variety of different ways. For example, one participant may sleep 8 hours consistently throughout the week whereas another may not sleep at all Monday night and sleep 12 hours on Wednesday and Thursday nights to make up for the loss of sleep on Monday. The next set of analyses attempts to address this phenomenon in a very rudimentary fashion to point out avenues for future investigation.

First standard deviations were calculated using the mean weekday and weekend sleep for each individual. These data were then entered into a linear regression model with the covariates in step 1 and then the variable of interest (i.e., individual standard deviations) in step two. Results indicate a non-significant relationship ($p = .097$) suggesting that the amount of individual variability that this sample experienced was not a good predictor of individual performance.

Next, difference scores were calculated using the means of three sleep periods (i.e., average daily total sleep time, average weekday total sleep time, & average weekend total sleep time). To examine variability across both phases, average daily total sleep time (i.e., a proxy for their theoretical sleep need) was subtracted from average weekday and average weekend total sleep time and the difference scores (i.e., accumulated weekday sleep debt and weekend extension) were used for analysis. A linear regression analysis was conducted to determine whether variability in weekday sleep predicted performance on the BART during the restricted phase. Step 1

included all the covariates of interest and step two included the weekday sleep debt variable. Results revealed that weekday sleep debt approached significance ($p = .09$) accounting for 8% of the variance above and beyond what the covariates contributed. To examine daily variability during the restricted period (i.e. weekdays), the average daily total sleep time was subtracted from the amount of sleep acquired on each day of the week for each individual and the difference scores were obtained. To examine this relationship further, a linear regression analysis was conducted to determine if a predictive relationship existed between the amount of sleep debt on a Thursday night and BART following the restricted phase. Similar to previous models, the covariates were entered in first then the Thursday night sleep debt variable followed. These results also approached significance ($p = .08$, R^2 change = .09), accounting for an appreciable amount of variance.

Chapter 4: Discussion

Previous literature has shown the associations between sleep restriction and daytime functioning with regard to academics, cognitive function, and mood. However, there is a paucity of research that has examined disinhibited behavior (e.g., impulsivity, sensations seeking, and risk taking propensity) as another variable linked to inadequate sleep. The current study examined the impact of the natural adolescent restriction/recovery process on daytime function. It was hypothesized that within subject behavior on a Friday after a full week of cumulative sleep loss (i.e., sleep debt), as compared to Sunday evening after 2 nights of extended sleep (i.e., sleep

recovery), would indicate significantly higher rates of working memory deficits, negative mood, and disinhibition. Overall, the primary results of this study did not support the specific aims, however, preliminary analyses revealed that weekday total sleep time was a significant predictor of problem behavior by parent report and within subject analyses showed significant changes in reaction times across phases.

Additional post hoc analyses showed interesting relationships between adolescent sleep and sleep debt that should be explored in future studies. Specifically, post hoc exploratory analyses revealed that high variability between weekday & weekend sleeping patterns was associated with externalizing behaviors in general, increased risk-taking propensity following both the restricted and recovery phases, as well as impulsivity following the restricted time period. Additionally, variability in interindividual sleeping behaviors, specifically the level of sleep debt on Thursday nights, also appeared to be a relevant factor related to BART performance during the same time period. The following section will begin with a discussion of each result and conclude with remarks regarding study limitations and future directions.

Relationship Between Sleep Debt and Working Memory, Current Mood, & Disinhibition

Previous studies have shown that persistent sleep restriction is related to a host of impairments in daytime function (Wolfson & Carkadon, 1998; Durmer & Dinges, 2005; Millman 2005). With regard to cognitive function, the adult literature has revealed consistent deficits in working memory, alertness, and performance (Balkin, 2004; Kilogore, 2006, Roehrs et al., 1990; Van Dongen et al., 2003, Van Dongen

2004). However the child and adolescent literature has not been as consistent. Sadeh, Gruber, & Reviv (2003) found deficits in neurobehavioral function using a protocol of moderate sleep restriction in a school-age population. Carskadon and colleagues (1981a) used a sample of adolescents and found decrements in recall as well as speed and accuracy after a prolonged sleep deprivation but found that acute deprivation was not as impairing. Finally in a study using a preadolescent population, restricted sleep was related to impairments in tests of verbal creativity and abstract concepts, but did not impact verbal memory, visual memory, learning, recall, or problem solving (Randazzo, 1998).

The within subject results of this study add to the inconsistency in the literature regarding adolescent cognitive performance decrements following a restricted sleep period. The natural sleep restriction that the adolescents endured over a span of 5 consecutive days produced impairments in reaction time however did not have a significant impact on other aspects of this particular working memory task after controlling for age, gender, and order of entry into the study. The significant findings suggests that reaction time may be the most susceptible to impairment related to inadequate sleep, which could relate to the high incidence of drowsy driving accidents as well as other unintentional injuries in this population. However the non-significant findings could be related to the nature of the study as well as the type of task administered. This study utilized a naturalistic design as opposed to an experimental design that is often employed in similar studies. This difference in study design may have limited the amount of impairment evidenced in this sample. Although the naturalistic design is closer to real life experience an experimental

design allows for more rigorous control of participant sleep with greater ability to restrict participant sleep to low levels and greater opportunity for subjects to obtain optimal levels of sleep during the recovery period. In addition, the study by Carskadon and colleagues utilized a 6-day deprivation protocol as compared to the five-day restriction protocol used in this study, which may explain the contradictory finding. With regard to the type of tasks utilized in this study, it is possible that the letter n-back task as a whole was not sensitive enough to pick-up impairments in the other domains that may be experienced by this population. It may be more appropriate to investigate more real-world relevant ecologically valid cognitive tasks potentially more susceptible to restricted sleep. Measures of decision making ability and judgment may be more likely to show impairment and more relevant to adolescent daily life.

The extant literature on associations between inadequate sleep and mood disturbance in adolescents is more robust and consistent. Previous studies have shown that persistent mood disturbance and depressed mood states have been linked to impaired sleep as well as clinically diagnosed disorders of sleep. A seminal article by Wolfson and Carskadon (1998) showed that high school students with shorter weekday total sleep time and longer bedtime weekend delays reported higher rates of depressive mood compared to their peers with longer weekday total sleep time and less than a 60 minute discrepancy between weekday and weekend sleep. Results of the current study did not show significant within subject differences on current mood after controlling for order, age, and gender. Preliminary analyses revealed that gender was significantly correlated with ratings of current mood suggesting that

gender may be more relevant in predicting mood fluctuations in this sample than sleep loss itself. Plausible explanations for this departure from previous findings are similar to those discussed regarding decrements in cognitive function but also include the frequency with which mood was monitored in this sample. Mood was measured at two time points during this study, following the restricted phase and following the recovery phase. These two time points may not adequately reflect the fluctuations in mood that an individual experiences throughout the week as a result of daily restriction. There is data to suggest that subjective mood may be susceptible to time of day effects such that increased levels of subjective sleepiness may be more prevalent around 10:00am (Dinges, 1997). Daily or hourly mood monitoring measures might be more sensitive to these daily fluctuations. Because we only collected mood on two discrete time points, this type of specificity is not possible but should be considered for planned systematic extensions of this work.

The concept of disinhibited behavior being linked to inadequate sleep has been anecdotally discussed for some time but the empirical literature regarding this association has been sparse. Some studies have shown a relationship between general behavioral problems and inadequate sleep in adolescents (Leotta et al., 1997; Morrison, McGee, & Stanton, 1992; Sussman et al. 2007; Wolfson & Carskadon, 1998) as well as the link between sleep restriction and specific risky variables such as suicidality, drowsy driving, driving/riding while drunk, alcohol use/abuse, as well as other forms of substance use/abuse in a variety of populations (Arnedt 2005; Carskadon, 2002; Johnson & Breslau, 2001; Liu, 2004; Wong Brower, Fitzgerald, & Zucker, 2004). However, only one other study to date has formally assessed the link

between inadequate sleep and risk-taking behavior as a broad domain (O'Brian & Mindell, 2005). In this cross sectional study, retrospective report was used to find that adolescents who reported shorter weekday total sleep time and higher levels of weekend delay (i.e. the difference between their weekday bedtime vs. their weekend bedtime) also reported significantly higher levels of risk-taking behaviors. Although interesting, the reliance on retrospective self-report certainly limits interpretation of these results.

The primary aim of this study was to examine the extent to which a relationship existed between naturally occurring sleep debt and measures of disinhibition purported to underlie risk-taking behavior in an adolescent population. When the data were examined globally, two findings were revealed. First weekday total sleep time significantly predicted total behavioral problems as measured by parent report. Secondly, the sample did not evidence elevated levels of disinhibition as measured by the BART, SSS, DDT, and the EPI following sleep restriction, after controlling for order, gender, and age. Preliminary analyses did indicate significant correlations between order and risk-taking propensity as well as age and delay discounting, which may have mediated or moderated any possible relationship between sleep and disinhibition. However minimal fluctuations did exist within the sample denoting slight individual differences in performance. Although a previous study found an association between inadequate sleep and self-reported real-world risky behaviors (O'Brian, 2005), this study did not show a significant relationship between restricted sleep and measures of disinhibition. It is possible that significant impairment was not found in the current sample due to the fact that the participants

were not restricted enough and or did not fully recover to optimal levels of sleep. This would cause them to perform similarly following both conditions because they either obtained enough sleep to function or were still under the influence of weekday-restricted sleep. Previous research has used 3-6 hours as a target range of restricted sleep that is adequate enough to show impairment (Belensky et al., 2003; Carskadon, & Dement, 1984; Dinges et al., 1997). As noted earlier, the participants in this study averaged approximately 7 hours of sleep during the restricted phase. Conversely, emerging data suggests that an extended period of recovery time may be needed and that the amount of recovery time may be related to the extent of the restriction. The gold standard for the number of hours suggested for recovery sleep is at least 10 hours per night, participants in this study received an average of 8 ½ hours. However there is no definitive data that specifies how many nights of recovery may be needed. Recent data suggests that individuals vary in the amount of time it takes them to recover from restricted sleep (i.e. the number of days) and that the magnitude of restriction may be related to an increase in the amount of time needed to recover (Rupp, 2008). Another plausible explanation for this null finding could be related to the sample size, as an examination of the means shows that the overall sample was riskier following the restricted phase. A larger sample in future studies may allow for significant differences to surface.

Post Hoc Exploratory Analyses

Initial observations regarding the data in this study revealed several interesting potential relationships that warranted further exploration. Given the high discrepancy

between the average amount of sleep that the participants obtained during the weekday and the average amount of sleep they obtained on the weekend it was important to determine whether there was a relationship between the magnitude of this discrepancy and evidence of daytime impairment. Preliminary data showed a relationship between level of discrepancy and parent report of externalizing behaviors, a construct often related to performance on the BART. Subsequent post hoc analyses were then conducted to determine whether individuals who obtained a substantial amount of sleep on the weekend compared to what they obtained during the weekdays performed better on measures of disinhibition, working memory, and current mood. As expected, significant differences were found on participant BART performance however surprisingly, differences were also found on the number of commission errors committed on the n-back task following the restricted period. Additionally BART performance approached significance following the recovery phase as well. The implications of these finding are important and require further investigation. The fact that BART was significantly different between the two groups following the restricted period could mean that the severe restriction during the week in the high discrepancy group was at a level that was extreme enough to cause impairment beyond what was seen in the sample as a whole. In the event that this finding would also carry over to the recovery time period it is possible that teens that engage in this highly variable weekday to weekend pattern of sleep also have a riskier personality in general, an individual difference factor that may lead to higher risk-taking propensity regardless of the situation. The additional finding showing that discrepancy score was also related to externalizing behaviors adds more credence to

the latter explanation. Previous studies have shown that significant weekend oversleep (i.e. the discrepancy between weekday and weekend total sleep time) as well as weekend delay (i.e. the difference between weekday bedtime and weekend bedtime) have been associated with global decrements in daytime function (Carskadon, 1998; Chung, 2008; O'Brian & Mindell, 2005). With regard to the fact that the more consistent sleepers were shown to have significantly higher rates of commission errors following the restricted period, it is possible that they were not as able to handle restricted conditions as their more inconsistent counterparts. Presumably, the high discrepant group was acclimated to the up and down nature of their ability to obtain sleep. Whereas, the low discrepancy group is generally more consistent such that when they do encounter sleep restriction they are less able to handle its effects and therefore more susceptible to impairment. However, given that impairments in other areas of working memory such as reaction time and accuracy were not found, that argument is somewhat weakened. It is also possible that this is a spurious finding as the effects size is small and it is counter intuitive. One might hypothesize that more commission errors would be likely following sleep restriction given the findings from previous literature and that if any variable would be vulnerable to the discrepancy, reaction time would be the likely candidate as it was more vulnerable to within subject changes in earlier analyses.

The degree of individual variability in acquired sleep throughout the week also was noteworthy. A Review by Van Dongen and colleagues (2005) highlighted interindividual variations in sleep parameters, sleepiness, responses to sleep deprivation, and manifestations of sleep disorders. Similarly, Klerman & Dijk (2005)

revealed how interindividual differences in sleep duration relate to sleep debt. They found that individuals with shorter habitual sleep duration have higher levels of sleep debt and that this variability may reflect variations in self-selected sleep restriction or wake extension.

In the current study, individual sleep patterns were examined to show a visual representation of the high level of variability in individual sleep habits throughout the week. Although group averages may depict a tendency for the group to restrict during the week and extend on the weekend, individual participants do not generally have the same exact sleeping pattern on a night-to-night basis. Some adolescents may obtain adequate amounts of sleep on 1 or 2 weeknights and restrict on the others such that they average out to an inadequate total sleep time. Alternatively, others may restrict consistently throughout the weekdays. Accordingly, some may have huge discrepancies during the week in the amount of sleep obtained while others, though still variable, may have less of a discrepancy. One might expect that those with higher variability may experience more of an impact in their daily functioning. Post Hoc exploratory analyses of this phenomenon revealed that the amount of variability as represented by standard deviations from their average sleep was not significantly associated with risk-taking propensity after a week of cumulative sleep debt. Additionally, the level of sleep debt experienced on the night before their assessment also appeared to be approaching significance but was not definitively linked. These associations need further clarification through future studies to determine if the degree to which the individual restricts their sleep from what may be viewed as their individual theoretical need the night before determines their degree of riskiness on the

subsequent night. Additionally, it would be important to investigate whether there may be more of an immediate impact of restriction such that risky behavior is more likely closer to the restricted period.

Limitations & Future Directions

Although the study design does not allow us to determine causation or assign directionality, this study provides a critical step towards understanding the complex relationship between sleep and risky behaviors. However, it is not without limitations. To begin with, it is important to note that the number of total analyses conducted using this small sample makes the results susceptible to experiment wise error so results should be interpreted with caution.

Secondly, this was not an experimental study where participant's sleep was manipulated and monitored by study staff continuously for a predetermined length of time. Instead, this study relied on expected differences in sleeping habits that would exist following a full weekday period (i.e., sleep debt phase) and a full weekend period (i.e., sleep recovery phase). This naturalistic design has its strengths in that it allows us to examine typical patterns of adolescent sleep in the context of daily environmental demands, however, more rigid control of sleep parameters should be used in future studies to reduce the amount of individual variability allowing for a clearer understanding of how sleep impacts risk-taking behaviors. An example of the controlled sleep procedures that might be used in a future study would include a within subjects design where each subject's habitual nightly sleep was monitored for a 2 week period at home using sleep log and actigraphy. Then each subject would be

asked to modify or maintain their sleep habits such that they receive a week of adequate opportunity to sleep at home (i.e. ≥ 9 hrs) with no more than 1 hour fluctuations in either direction between nightly bedtimes and daily total sleep times throughout the week. Finally they would undergo a 13 day in lab procedure where they would have 3 days of adequate sleep followed by 5 days of restricted sleep (i.e., 4 hours of total sleep time) and concluding with 5 days of recovery sleep (i.e., ≥ 10 hrs of total sleep time). Recent research has revealed that time to recovery can vary from person to person but is likely related to the level of “reserve” sleep one accrues before the restricted period (Jay et al., 2007; Rupp, 2008). This line of research has not been investigated with adolescents but it would be important to consider in future studies. Additionally, it would be interesting to investigate whether various levels of restriction influence this relationship in adolescents (i.e., 6 hours of restricted sleep vs. 5 hrs vs. 4 hrs) as well as whether acute restriction versus accumulated debt has a more potent effect on risk-taking behavior.

Another limitation can be related to the discordant findings of this study in relation to mood and cognitive impairment associated with sleep restriction. As previously discussed it is possible that the cognitive task used in this study was not sensitive enough to pick up all the impairments experienced by adolescents in the working memory domain as a result of the weekly restriction and recovery cycle, if the impairments are experienced at all. Future studies should use more ecologically valid cognitive tasks that might be more relevant to an adolescent population and indicate real-life areas of cognitive impairment (i.e. moral judgment & social decision making) associated with sleep loss. A recent study by Killgore and colleagues (2005)

showed significant findings related to restricted sleep and decision making in an adult population. This relationship may also hold true with adolescents and help to elucidate why risky behaviors are so prevalent in this group. Furthermore, it might be important to record mood ratings on a daily basis or multiple times throughout the day to capture any variability that may exist within the individual as well as between individuals. There is a possibility that adolescents might be more vulnerable to impairments in mood at a given time during the day or on a given day during the restricted period or under severe academic pressure (i.e. testing & presentation situations).

Next, although the design of this study provides information on how sleep restriction may be related to risk-related personality variables, it is not possible to definitively determine how these findings may relate to real-world risk taking behavior of study participants. It is important for future studies to identify the current and past risky behaviors that teens are engaging in to see if those that have more of a risk-taking propensity using this paradigm also have greater participation in more real-world risky behaviors. Behaviors such as driving while drowsy, unintentional injury, alcohol and drug use, risky sexual practices, and encounters with the law should be included as they are often preventable and appear to be prevalent in adolescent populations. It would also be interesting to see if the increase in risk-taking propensity would be more associated with a particular form of real world risk behavior than another.

Additionally, this study was cross sectional in nature, which limits the generalizability of these findings. Studies that consider other developmental periods

would be beneficial to determine at what age psychoeducational or prevention strategies might be useful as well as to elucidate whether adult functioning and sleep patterns are associated with patterns found earlier in life. These studies could either be within subject longitudinal designs or cross sectional designs that allow for comparisons of this association across the developmental spectrum.

Despite limitations, this study provides a unique glimpse into the relationship between naturalistic sleep restriction and risk-taking propensity in an adolescent population. It highlights the potential importance of individual variability within this association as well as the impact of variability across the week in daytime functioning. Future studies should include rigorous experimental designs that closely monitor sleep procedures and manipulate them systematically. Dose response paradigms should be considered to determine if the type of sleep loss and the amount of restriction differentially impact daytime impairment. In addition, individual difference factors such as variability in habitual sleep duration, individual expectations of sleep and sleep loss, past history, and cultural norms/practices should be investigated in relation to risky behaviors associated with sleep debt. Research in this area might help to reveal risk and protective factors that can be used to inform prevention strategies geared towards reducing injuries and fatalities in the adolescent population. Furthermore, collaborations across various disciplines should be used to investigate this phenomena at different levels. It is possible that basic research that focuses on brain activity or neurochemistry might inform more clinical research efforts and vice versa. It would be important to link more biologically based findings to real-world past and current risk-taking in an effort to make the findings more

translational in nature. Finally, examining the association between sleep loss and risk-taking propensity across the developmental spectrum would also be an important addition to this literature. There is data to suggest that this variable pattern of sleep from weekday to weekend is evidenced in school age children and it is possible that there is a link between establishing this pattern early in life and impairment in adulthood.

Appendix

Sensation Seeking Scale

It is important you respond to all items by circling only one choice. We are interested only in your likes or feelings, not in how others feel about these things or how one is supposed to feel. There are no right or wrong answers as in other kinds of tests. Be frank and give your honest appraisal of yourself.

1. I would like to explore strange places.	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
2. I get restless when I spend too much time at home.	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
3. I like to do frightening things.	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
4. I like wild parties.	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
5. I would like to take off on a trip with no pre-planned routes or timetables.	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
6. I prefer friends who are excitingly unpredictable.	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
7. I would like to try bungee jumping.	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
8. I would love to have new and exciting experiences, even if they are illegal.	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

Delay-Discounting Task

For each of the next 27 choices, please circle which one you would prefer if given the choice between the two: would you rather have the smaller reward today, or wait the specified number of days and take the larger reward? Please answer EVERY question.

Please take the choices seriously: they may be for REAL MONEY. If you have any questions regarding this, please ask.

- | | |
|----------------------------------|---------------------|
| 1. Which would you rather have? | |
| a. \$49 today | b. \$60 in 89 days |
| 2. Which would you rather have? | |
| a. \$47 today | b. \$50 in 160 days |
| 3. Which would you rather have? | |
| a. \$54 today | b. \$80 in 30 days |
| 4. Which would you rather have? | |
| a. \$27 today | b. \$50 in 21 days |
| 5. Which would you rather have? | |
| a. \$41 today | b. \$75 in 20 days |
| 6. Which would you rather have? | |
| a. \$55 today | b. \$75 in 61 days |
| 7. Which would you rather have? | |
| a. \$34 today | b. \$35 in 186 days |
| 8. Which would you rather have? | |
| a. \$34 today | b. \$50 in 30 days |
| 9. Which would you rather have? | |
| a. \$22 today | b. \$25 in 136 days |
| 10. Which would you rather have? | |
| a. \$80 today | b. \$85 in 157 days |
| 11. Which would you rather have? | |
| a. \$14 today | b. \$25 in 19 days |
| 12. Which would you rather have? | |
| a. \$19 today | b. \$25 in 53 days |
| 13. Which would you rather have? | |
| a. \$15 today | b. \$35 in 13 days |
| 14. Which would you rather have? | |
| a. \$25 today | b. \$30 in 80 days |
| 15. Which would you rather have? | |
| a. \$33 today | b. \$80 in 14 days |
| 16. Which would you rather have? | |
| a. \$54 today | b. \$55 in 117 days |
| 17. Which would you rather have? | |
| a. \$54 today | b. \$60 in 111 days |

- | | |
|----------------------------------|---------------------|
| 18. Which would you rather have? | |
| a. \$11 today | b. \$30 in 7 days |
| 19. Which would you rather have? | |
| a. \$69 today | b. \$85 in 91 days |
| 20. Which would you rather have? | |
| a. \$78 today | b. \$80 in 162 days |
| 21. Which would you rather have? | |
| a. \$20 today | b. \$55 in 7 days |
| 22. Which would you rather have? | |
| a. \$31 today | b. \$85 in 7 days |
| 23. Which would you rather have? | |
| a. \$24 today | b. \$35 in 29 days |
| 24. Which would you rather have? | |
| a. \$40 today | b. \$55 in 62 days |
| 25. Which would you rather have? | |
| a. \$67 today | b. \$75 in 119 days |
| 26. Which would you rather have? | |
| a. \$28 today | b. \$30 in 179 days |
| 27. Which would you rather have? | |
| a. \$25 today | b. \$60 in 14 days |

EPI – Impulsivity Subscale

Instructions: Please answer each question by putting a circle around the ‘YES’ or the ‘NO’ following the questions. There are no right or wrong answers, and no trick questions. Work quickly and do not think too long about the exact meaning of the question.

1. Do you often buy things on impulse?	YES	NO
2. Do you generally do and say things without stopping to think?	YES	NO
3. Do you often get in a jam because you do things without thinking?	YES	NO
4. Are you an impulsive person?	YES	NO
5. Do you usually think carefully before doing anything?	YES	NO
6. Do you often do things at the spur of the moment?	YES	NO
7. Do you mostly speak without thinking this out?	YES	NO
8. Do you often get involved in things you later wish you could get out of?	YES	NO
9. Do you get so ‘carried away’ by new and exciting ideas that you never think of possible snags?	YES	NO
10. Do you need to use a lot of self-control to keep out of trouble?	YES	NO
11. Would you agree that almost everything enjoyable is illegal or immoral?	YES	NO
12. Are you often surprised at people’s reactions to what you do or say?	YES	NO
13. Do you think an evening out is more successful if it is unplanned or arranged at the last moment?	YES	NO
14. Do you usually work quickly, without bothering to check?	YES	NO
15. Do you often change your interests?	YES	NO
16. Before making up your mind, do you consider all the advantages and disadvantages?	YES	NO
17. Do you prefer to “sleep on it” before making decisions?	YES	NO
18. When people shout at you, do you shout back?	YES	NO
19. Do you usually make up your mind quickly?	YES	NO

Demographics Questionnaire

Child's Gender: (0) Female ☐ (1) Male ☐

Child's Age: _____

Child's Grade in school: _____

Child's Race/Ethnicity:

- | | |
|---|--|
| <input type="checkbox"/> (1) White/Caucasian | <input type="checkbox"/> (5) Hispanic/Latino |
| <input type="checkbox"/> (2) Black/African American | <input type="checkbox"/> (6) Native American/American Indian |
| <input type="checkbox"/> (3) Asian/Southeast Asian | <input type="checkbox"/> (7) Biracial/Multiracial |
| <input type="checkbox"/> (4) Other | |

Age (biological mother): _____

Age (biological father): _____

Does the biological father live with the family? Yes ☐ No ☐

If no, does another adult male non-family member live with the family? Yes ☐ No ☐

Monthly Income (all sources after taxes): \$ _____

Monthly Debt (all sources): \$ _____

Race/Ethnicity of biological mother:

- | | |
|---|--|
| <input type="checkbox"/> (1) White/Caucasian | <input type="checkbox"/> (5) Hispanic/Latino |
| <input type="checkbox"/> (2) Black/African American | <input type="checkbox"/> (6) Native American/American Indian |
| <input type="checkbox"/> (3) Asian/Southeast Asian | <input type="checkbox"/> (7) Biracial/Multiracial |
| <input type="checkbox"/> (4) Other | |

Race/Ethnicity of biological father:

- | | |
|---|--|
| <input type="checkbox"/> (1) White/Caucasian | <input type="checkbox"/> (5) Hispanic/Latino |
| <input type="checkbox"/> (2) Black/African American | <input type="checkbox"/> (6) Native American/American Indian |
| <input type="checkbox"/> (3) Asian/Southeast Asian | <input type="checkbox"/> (7) Biracial/Multiracial |
| <input type="checkbox"/> (4) Other | |

Education for biological mother (place a check in the box below):

1. ☐ Some High School (list highest grade completed _____)
2. ☐ High School Degree or GED
3. ☐ Technical or Trade School
4. ☐ Some College (list highest year completed _____)
5. ☐ College Degree
6. ☐ Advanced degree (for example, MSW, MA, PhD, JD, RN)

Education for biological father (place a check in the box below):

1. ☐ Some High School (list highest grade completed _____)
2. ☐ High School Degree or GED
3. ☐ Technical or Trade School
4. ☐ Some College (list highest year completed _____)
5. ☐ College Degree
6. ☐ Advanced degree (for example, MSW, MA, PhD, JD, RN)

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