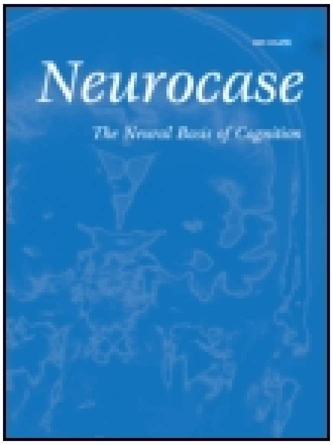

Neurocase: The Neural Basis of Cognition
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/nncs20

The relationship between sleep patterns and attention levels

Dubi Lufi[a]

[a] Behavioral Sciences, Yezreel Valley College, Yezreel Valley, Israel

Published online: 01 Oct 2013.

To cite this article: Dubi Lufi (2014) The relationship between sleep patterns and attention levels, Neurocase: The Neural Basis of Cognition, 20:5, 591-598, DOI: 10.1080/13554794.2013.841955

To link to this article: http://dx.doi.org/10.1080/13554794.2013.841955

Neurocase, 2014
Vol. 20, No. 5, 591–598, http://dx.doi.org/10.1080/13554794.2013.841955

The relationship between sleep patterns and attention levels

Dubi Lufi

Behavioral Sciences, Yezreel Valley College, Yezreel Valley, Israel

Fifty-nine adults slept five nights with an Actigraph and answered two questionnaires related to sleeping quality and morningness/eveningness preferences. Next they performed a computerized attention task (the mathematics continuous performance test (MATH-CPT)) to assess various measures of attention. Results showed significant correlations between six attention variables and two measures of sleep assessed by the Actigraph. Linear regression with sleep variables as independent variables, and measures of the computerized test as dependent variables showed that sleep measures explained 30% of the variance of the score in the "final attention formula" of the test, and 27% of the "rate of response."

Keywords: Sleep patterns; Sleep efficiency; Attention; Continuous performance test; Actigraph.

One of the most important daily activities, necessary for appropriate cognitive functioning, is sleep. Although the exact function of sleep is not clearly understood, it is known that sleep quality and sleep quantity are major factors in sleep mechanism. This does not explain why humans need to spend approximately one-third of his or her life in sleep (Dinges, Maislin, Mullington, & Van Dongen, 2003). Recently, there has been increasing evidence that sleep is essential for executive functions needed for learning and memory (Stickgold & Walker, 2008). It is hypothesized that during sleep, some memory traces might be replayed (Peigneux et al., 2004), modified (Walker & Stickgold, 2004), stabilized (Ellenbogen, Payne, & Stickgold, 2005), or even enriched (Huber, Ghilardi, Massimini, & Tononi, 2004).

It was observed that sleep deprivation caused a reduction in cognitive functioning, just as the recovery of sleep loss improved cognitive functioning (Dinges & Van Dongen, 2005). Dinges et al. (2003) assessed the effect of various amounts of sleep on different cognitive functions. They reported that complete or partial sleep deprivation caused a reduction in memory, learning, logical thinking, mathematical abilities verbal processing and decision-making. They summarized their study by stating that chronic sleep restriction, in normal adults, no more than six hours or less may be equivalent to two nights of total sleep deprivation. Similarly, in their research, Chee, Parimal, Tan, and Zagorodnov (2010) found that straight 24 hours of sleep deprivation led to participants' lower quality, slower recognition, and poorer memory in a task involving face recognition. The effect of sleep deprivation is even more pronounced in populations with permanent sleep deprivation, as can be found in shift workers. Czeisler et al. (2005) assessed shift workers and found that 5–10% of them had severe sleep dysfunctions as a result of being awake during the night; in addition, they are usually sleepy during the day. In their study, tiredness and lack of alertness caused lower cognitive functioning, among them attention and memory. Others

Address correspondence to Dubi Lufi, Behavioral Sciences, Yezreel Valley College, Yezreel Valley, 19300 Israel. (E-mail: dubilufi@gmail.com; dubil@yvc.ac.il).
I would like to thank Professor Orna Tzischinsky for her advice and assistance in the writing of this paper.

(Johnson, Brown, & Weaver, 2010) reported an inverse relationship between psychomotor performance, and hours of sleep among night-shift nurses.

The research on sleep and cognitive functioning has been expanded mainly in the study of sleep deprivation. Sleep deprivation was found to be associated with a lessening of basic cognitive functions comprising alertness, reaction time, vigilance, decreased attention allocation to stimuli, and a more rapid loss of attention to repeated stimuli (Westensten et al., 2002), and memory, (Stickgold, 2005). Other cognitive functions found as associated with sleep deprivation were: learning and concentration (Dahl, 2005; Taras & Potts-Datema, 2005) and decline in neurological functioning and impaired mood and behavior (Talbot, McGlinchey, Kaplan, Dahl, & Harvey, 2010). Reductions in alertness and cognitive performance resulting from sleep loss are a threat to productivity in school performance, military, and industrial operations (Westensten et al., 2002). Sleep loss may reduce motivation, decrease speed of functioning, degrade accuracy, impair the ability to maintain wakefulness, demean cognitive performance, and increase subjective sleepiness (Goel, Rao, Durmer, & Dinges, 2009). While there was substantial evidence to suggest that sleep deprivation impairs cognitive performance of simple tasks involving alertness and vigilance researches in high-level complex skills were relatively unaffected by sleep deprivation because of the interest that such skills generate and the effort made to overcome sleepiness (Harrison & Horne, 2000). Various hypotheses were developed to explain the phenomenon of reduction of the performance quality as a result of sleep deprivation. The "lapse hypothesis" (Dinges & Kribbs, 1991) explained that in a state of sleep deprivation performance was punctuated by short periods of time of low arousal in which performance lapses occur, and the person was unable to respond to the task he/she faces. The "state instability hypothesis" postulated that sleep deprivation affected mostly performance fundamentally sensitive to instability such as variability in sustained attention. The result of such a situation was that lapses in the performance increases as sleep deprivation and time on the task increases. However, very short periods of a descend performance may appear as a result of efforts to respond normally (Doran, Van Dongen, & Dinges, 2001). Further discussions of such hypotheses are beyond the scope of this paper.

The association between sleep and attention in normal adults who have regular sleep is scarce, although it has been established in several studies. Owens (2009) explained this association, stating: "From a theoretical perspective, there is substantial empirical evidence supporting an overlap in those central nervous system centers that regulate sleep and those that regulate attention/arousal, suggesting disruptions in one system might well have parallel effects on the other" (p. 93). Several studies assessed the effect of sleep on attention among children and adolescents. Lufi, Tzischinsky, and Hadar (2011) found that even one extra hour of sleep in the morning had a positive effect on attention functioning among adolescents. With this extra one hour of sleep, adolescents showed a better performance in attention level, rate of response, and less impulsivity. Similarly, Dahl (2005) found that among youngsters of 9–12 years of age, an additional 35 minutes of sleep improved their attention, memory, and reaction time. Gasol, Tzischinsky, and Lufi (2006) found similar results with 14-year-olds whose attention level improved after adding 38 minutes of sleep by going to bed earlier.

Based on existing knowledge about the connection between sleep and attention, the purpose of the present study was to assess the effect of objective sleep–wake patterns on various measures of attention among healthy young adults who had a regular night's sleep. More specifically, the study aimed to assess whether the rate of response, attention, impulsivity, and sustained attention are correlated with measures of sleep. To achieve this goal, the study used an Actigraph and questionnaires to assess sleep patterns while the attention level was assessed with a computerized test assessing various aspects of attention.

The ability to predict a cause and effect was limited due to the correlational nature of the study. Therefore, the hypothesis of the study was that positive correlations would be found among the main variables of attention measured by a computerized test: final attention formula, rate of response, standard deviation (SD) of rate of response, total impulsivity (anticipatory responses and fast wrong responses), and correct responses, to measures of sleep: sleep onset time (SOT), sleep wake-up time (SWT), sleep period time (SPT), time awake during the sleep (WDS), and sleep efficiency (SEF).

METHOD

Participants

Sixty-five young healthy Israeli adults volunteered to participate in the study. The age of the participants ranged from 19 to 30 (mean age =

24.22, SD = 2.30, 27 males and 32 females participated in the study). The participants were recruited by answering flyers posted in the area. The data of six participants were not included among the results due to incomplete data collected by the Actigraph. The final number of participants, therefore, was 59. Criteria for inclusion in the study were as follows: participants did not have any neurological disorder or specifically sleep disorders or Attention Deficit Hyperactivity Disorder (ADHD) as judged by the medical record each participant provided.

The clinical experiment conformed with the principles outlined by the Declaration of Helsinki. The complete study protocol was approved by the institutional ethics committee of the Yezreel Valley College. After receiving a complete description of the study, all participants gave their written informed consent. All of them volunteered to participate in the study without any financial reward.

Instruments

All the subjects completed two self-administered questionnaires that included:

Mini sleep questionnaire (MSQ; Zomer, Peled, Rubin, & Lavie, 1985). The questionnaire aimed at assessing sleep disorders (insomnia and hypersomnia). The questionnaire is used to detect and sort-out participants with sleep disorders. The questionnaire includes ten questions in a Likert-type scale with seven options ranging from 1 = Never to 7 = Always. An average of the scores of all the answers indicates the possibility of sleep disorder and their intensity. A sample question was "Do you have difficulty in falling asleep?" Chronbach Alpha reliability of the questionnaire in the present study was .70.

Self-assessment questionnaire to determine morningness–eveningness (Horne & Ostberg, 1976). This was a short questionnaire of seven questions aimed at assessing the preference of the participants, either for activity during the day (morningness) or activity during the evening (eveningness). The goal of using this questionnaire is to assess a possible effect of morningness/eveningness preference with measures of attention. A median split score of the test in the study (9.00) was used to divide the participants into two groups of morningness or eveningness type. Chronbach Alpha reliability of the questionnaire in the present study was .80.

Actigraph (AMI, Ardsley, NY, USA). It is a small device, like a wristwatch, worn around the wrist of the non-dominant hand. The device weighs 57 grams and its size is 1.3 × 4.0 cm. The Actigraph included a computerized accelerometer, 32 kilobytes of memory, and a battery that enables operation for up to two weeks. The device records movements of the non-dominant wrist. Data were collected in one-minute epochs, and analyzed by a computer. The Actigraph is used for objective assessment of sleep over five consecutive nights. Use of the Actigraph for sleep research under natural conditions has been found in previous studies to have adequate reliability and validity for research (Acebo et al., 1999). Actigraphs were worn throughout the five nights at the beginning of the study while they slept in their homes. Lying down on the bed was marked by pressing a button to set on the Actigraph, named "event marker," while the end of sleep period was marked by another event marker when the participant woke up in the morning. The participants were instructed to press the button when they lay down in the night and when they woke up in the morning.

Activity data were downloaded and analyzed using the ActionW software (Version 2, using Sadeh algorithm #20; Mini-Act, AMA-32, AMI, Ardsley, NY, USA). The Actigraph is used to determine the SOT: the first minute of three minutes of consecutive sleep as recorded by the algorithm; SWT: the last minute of three minutes of consecutive sleep just before the end of the sleep period; SPT: the time between the first and the last minutes of sleep; and WDS: accumulation of the time the participant was awake during the night sleep measured in minutes. Measures also included SEF (reported in percentages, using the following formula: sleep time period/time in bed × 100). Time in bed was calculated from the time participants pressed the event marker when they entered the bed to the time when they pressed again the event marker when they woke up in the morning. All these measures were important variables of sleep measured by the Actigraph.

The mathematics continuous performance test[1] (MATH-CPT, Lufi & Fichman, 2012). It is a computerized CPT-type test designed to assess attention. The MATH-CPT uses a sequence of 450 simple mathematical problems involving addition, subtraction, multiplication, and division. The answer is never greater than nine and projected

[1]A research version of the MATH-CPT is available without charge from the author.

on a computer screen to serve as a visual stimulus. During the test, one problem appears on the screen together with a result that could be right or wrong (e.g., 1 + 4 = 5; or 4 × 2 = 6). The participants observed one problem at a time on the computer screen and had to decide whether the solution is correct or incorrect by pressing "1" for a correct answer or "2" for an incorrect answer. The test stimulus is more complicated than most other CPT-type tests, so an open reaction time allowed participants to react at their individual pace of activity. The test lasted approximately 10–20 minutes depending on the reaction time of each participant. The test includes the following main measures: final overall attention level formula to assess participant's overall attention level; rate of response (time taken to complete the test); SD of rate of response (a measure of reaction time variability); impulsive responses (a guessing fast response given at a speed less than .5 seconds and incorrect fast responses, both considered measures of impulsivity); and accuracy of responses (correct answers, considered a measure of attention). In addition, the results are presented in three and nine performance blocks from the beginning to the end of the test. The test's secondary measures were as follows: sustained rate of response (a measure of sustained attention of reaction time over nine parts of the test), sustained SD (sustained attention of the rate of response of SD over nine parts of the test), sustained correct responses (sustained attention of correct responses over nine parts of the test), sustained impulsivity (a measure of sustained attention of impulsivity over nine parts of the test). These four measures of sustained attention assess a possible reduction of performance on measures in their respective areas and are based on an algorithm designed specifically to assess these domains. The algorithm to assess sustained attention is based on a calculation of the nine blocks. Each block, from the first to the ninth in ascending order, contributed more to the measure of sustained attention, a single number assessing sustained attention in the four measures mentioned above. The "final overall attention level formula" is considered the most important item as it estimates attention (derived from the construction of the test by discriminant function analysis of all the MATH-CPT variables). In this formula, a score above zero indicated difficulty in attention, while a score below zero was considered within the normal range. During construction of the MATH-CPT, test–retest reliability after one week of testing indicated correlations ranging from .48 to .85 for the test's main measures. During the development of the MATH-CPT, a discriminant function analysis was used to compare a group with ADHD to a control group (without ADHD). The results indicated that the test can correctly identify 91.6% of the participants in both groups.

Procedure

The study took place in a regional academic college in Northern Israel. The Actigraph measures were taken during the week before performing the computerized test. Each participant slept five consecutive nights wearing the Actigraph before the performance of the MATH-CPT. Participants received explicit instructions on how to maintain their regular daily and sleep schedules. This meant going to bed and wake up at their regular time. Performing the MATH-CPT was done in the morning between 10 and 11. Each participant was tested individually in an empty room with a portable computer with a screen 15 inches in size. A numerical keyboard was attached to the computer and the participants used it while being tested. Prior to the beginning of the tests, each participant received instructions on how to use the MATH-CPT. Following the instructions, the participants answered 20 sample questions so they could become acquainted with the procedure of the test. This was the standard procedure of the MATH-CPT. Following the completion of the MATH-CPT, participants answered the questionnaires (self-assessment questionnaire to determine morningness–eveningness and the MSQ).

RESULTS

According to the Actigraph recordings of participants, they slept an average of 7 hours 20 minutes (SD = 1 hour 30 minutes) during the five nights of the research, starting at 00:29 AM (SD = 1 hour 20 minutes) and woke up at 7:49 AM (SD = 1 hour 10 minutes). The SEF, reported in percentages using the following formula: SPT/time in bed × 100, was 96.61% (SD = 3.57) and the time awake during the night sleep was 12 minutes 47 seconds (SD = 12 minutes and 4 seconds).

The MSQ self-assessment showed an average score of 2.72 points (SD = .75). This score was lower than the mid-score of normal population which was 3.50. This score was an indication of no deviation in sleep measures of the participants used in the study.

The average performance of the participants in the MATH-CPT was shown to be within a normal range of attention in the different measures of the test. A comparison of the present results to the normal group (Lufi & Fichman, 2012) showed that in all the variables of the MATH-CPT, the average of the participants in the present study deviated no more than 2/3 SD from the normal group.

The relationships between the variables measured by the Actigraph and the variables of attention measured by the MATH-CPT were assessed by a Pearson correlation. Results showed significant correlations between various measures of attention, final attention formula, rate of response, SD of rate of response with two measures of sleep as recorded by the Actigraph, the "SEF," and the "time awake during the night sleep." Between the following measures of the MATH-CPT and the sleep measures, there were no significant differences in total impulsivity, anticipatory responses, fast wrong responses, correct responses, sustained attention-time, sustained attention SD, sustained attention correct responses, and sustained attention-impulsivity. In these analyses, an alpha of .01 was used to reduce type 1 error, and the discussion was focused only on these variables having this significance level. These results are shown in Table 1.

In an attempt to understand better the meaning of these results and assess which sleep variable affected more the measures of attention, linear regression analysis was performed (the method used in this analysis was Enter). The statistics were carried out with the sleep variables measured by the Actigraph, as independent variables, and attention measures as measured by the MATH-CPT, as dependent variables. The regression was carried with each of the main measures of the MATH-CPT separately. The results showed that three sleep measures such as SEF, SOT, and SWT explained 30% of the variance of the score in the "final attention formula of the test," and 27% of the "rate of response." Both of these regressions were significant at the .01 level. Regressions of the other main variables of the MATH yield non-significant results. These results are shown in Table 2.

TABLE 2

A linear regression of sleep variables (sleep onset time, sleep period time, sleep wake-up time, and sleep efficiency) as independent variables and the main measures of the MATH-CPT as dependent variables (method used: Enter)

Variable	*r*	*r^2*	*F*	*Significance*
Final attention formula	.54	.30	4.95	.01
Rate of response	.52	.27	4.41	.01
SD of rate of response	.40	.16	2.21	.08
Total impulsivity	.28	.08	.90	.41
Anticipatory responses	.36	.13	2.44	.08
Fast wrong responses	.21	.05	.72	.55
Correct responses	.26	.07	.83	.52

Final attention formula = the formula assessing the overall attention level of the participant; rate of response = time taken to complete the test; SD of rate of response = SD of rate of response-consistency of the responses' speed; total impulsivity = a combination of anticipatory responses and fast wrong responses; anticipatory responses = guessing response faster than 500 milliseconds; fast wrong responses = wrong answers, answered faster than the average response time; total correct responses = total correct responses-measures of attention.

TABLE 1

Correlations between the main measures of the MATH-CPT and the measures of sleep efficiency found by the Actigraph ($N = 59$)

MATH-CPT/Sleep	*Sleep onset time*	*Sleep wake up time*	*Sleep period time*	*Sleep efficiency*[a]	*Time awake during the sleep*
[b]Final attention formula	−.13	−.09	.08	−.54**	.51**
[b]Rate of response	−.9	−.02	.13	−.52**	.54**
[b]SD of rate of response	−.13	−.03	.17	−.38**	.39**
[b]Total impulsivity	−.15	−.11	.04	−.18	.11
[b]Anticipatory responses	.06	−.08	−.15	−.29	.11
[b]Fast wrong responses	−.16	−.12	.04	−.17	.13
Correct responses	.12	.09	−.02	.17	−.13

**$p < .01$

[a]Sleep efficiency is reported in percentages, using the following formula: (sleep period time/time in bed × 100).

[b]Indicates that lower score is a better performance.

Final attention formula = the formula assessing the overall attention level of the participant; rate of response = time taken to complete the test; SD of rate of response = SD of rate of response-consistency of the responses' speed; total impulsivity = a combination of anticipatory responses and fast wrong responses; anticipatory responses = guessing response faster than 500 milliseconds; fast wrong responses = wrong answers, answered faster than the average response time; total correct responses = total correct responses-measures of attention.

The self-assessment questionnaire to determine morningness–eveningness (Horne & Ostberg, 1976) showed a median split score of 9.00 (SD = 3.98). This finding indicated a slight tendency of the participants to be within the "eveningness" type, which was closer to the eveningness threshold of 12 as compared with the score of 5, which was the top score for morningness. The median split score of the questionnaire divided the participants into two groups. Thirty-one participants were classified in the "morningness" preference while 28 were classified in the "eveningness" preference. A comparison of these two groups showed that the "morningness" group had a slightly better attention level assessed by the overall attention formula of the MATH-CPT; however, none of the measures of the MATH-CPT showed significant differences between the morningness or eveningness groups. The Actigraph showed significant differences in two measures regarding SOT and SWT. The "morningness" group went to sleep earlier: 00:10 AM ± 1:27 vs. the "eveningness" group: 01:03 AM ± 1:30 ($t = 2.61$, $p = .012$). The wake-up time was earlier in the "morningness" group: 7:25 AM ± 1:08 vs. evening preference: 7:58 AM ± 1:02 ($t = 2.77$, $p = .008$).

DISCUSSION

The results of the Actigraph, MATH-CPT, and MSQ showed that participants in the study had normal functioning of sleep–wake patterns and attention. These findings allowed researchers to verify their research goals without worrying about intervening variables of sleep or attention disturbances.

The primary goal in the present research was to find if variables of attention have been correlated with measures of sleep. Significant correlations between the main measures of the MATH-CPT with measures of sleep showed that two sleep variables ("SEF" and "WDS") had a strong association with the "rate of response," "SD of rate of response," and the "final attention formula." These findings support the study hypothesis about the strong connection between sleep and attention as stated by Owens (2009), who suggested the overlap of nervous systems regulate attention and sleep. Results of the regressions showed clearly that three measures of sleep, i.e., "SEF," "SOT," and "SWT" explained 30% of the variance of the "final attention measure of the test" and 27% of the "rate of response." "morningness" or "eveningness" tendency has no relationship to measures of attention.

These results showed clearly that measures of attention taken in the morning were associated mostly with the efficiency of the sleep in the previous night. They were similar to previous studies that showed the relationships between the various aspects of attention to measures of sleep and tiredness (Czeisler et al., 2005; Dinges et al., 2003), and impulsivity (Adan, Natale, Caci, & Prat, 2010; Anderson & Platten, 2011; Lufi et al., 2011). Anderson and Platten (2011) found that sleep deprivation led to a more impulsivity which resulted in a failure to inhibit a response. Lufi et al. (2011) found better performances in measures of attention, impulsivity, and rate of response as a result of an additional one-hour of sleep in the morning in "normal" adolescents. The results in the present study may be seen as a partial support to the "lapse hypothesis" (Dinges & Kribbs, 1991). This was discussed in the introduction, indicating that sleep deprivation or lower SEF may cause interruption of short periods of time of low arousal, in which performance lapses occur.

The knowledge that sleep could affect cognitive functioning is not new. Dinges et al., (2003) assessed the effect of various amounts of sleep on different cognitive functions. They reported that complete or partial sleep deprivation caused a reduction in memory, learning, logical thinking, mathematical abilities, verbal processing, and decision-making. The present study points that specifically sleep measures are associated with overall attention and rate of response. It had less association with other measures of attention such as, consistency in rate of response, impulsivity, accuracy of performance, and sustained attention. Attention level and rate of response were significant behavior variables influencing many aspects in life. School performance may depend heavily on an attention level, quality of driving is influenced significantly by attention level, and many other jobs, mainly those with more cognitive aspects need constant attention. Rate of response was often required in driving, sport activities, military functioning, and more. To maintain adequate levels of performance and high-quality results one needs an adequate level of attention. This can be translated into an adequate quality of sleep.

Limitations of the study include having a relatively small number of participants. Not having a homogeneous group of participants with regard to occupations and daily habits could reduce the ability to generalize the results of the present study. The use of a group of participants with ADHD may provide a better understanding with regard to the connection between sleep and attention. Although the issue of morningness/eveningness did not show any interesting results, this topic should be explored further, possibly with more than one questionnaire. Finally, using subjects suffering from sleep deprivation may shed more light on the contribution of sleep to a range of functions requiring attention.

The present study has several practical implications. Lack of sleep with lower SEF (as was shown by Czeisler et al. (2005)) may cause a reduction in attention level and affect other cognitive functioning. Possible practical aspects of the present study are: ensuring adequate sleep with sufficient SPT and high efficiency could improve the performance in various professions such as drivers, pilots, shift workers, physicians who work long night shifts, and military personnel. It was recognized that for various professions, there are recommendations for the amount of sleep they need before a working day. It is suggested that such a procedure may be regulated and enforced for the safety of the people who are using the services of employees in these professions. It is possible that those having better sleep quality, by going to sleep earlier, by having an appropriate diet in the evening that may not interfere with good sleep, or by not being interrupted during the sleep, may enhance their daily functioning by improving the attention level.

Future research should follow this paper to strengthen the results and to expand the knowledge on this topic. The effect of sleep upon attention should be investigated with different instruments assessing attention. Besides computerized measures, other cognitive measures such as paper and pencil tests along questionnaires to the participants of such studies. The same design can be used with people who are shift workers, such as pilots, drivers, etc. as well as those who have sleep disorders.

Original manuscript received 22 May 2013
Revised manuscript received 9 July 2013
Revised manuscript accepted 21 August 2013
First published online 3 October 2013

REFERENCES

Acebo, C., Sadeh, A., Seifer, R., Tzischinsky, O., Wolfson, A. R., & Hafer, A. (1999). Estimating sleep patterns with activity monitoring in children and adolescents: How many nights are necessary for reliable measures? *Sleep, 22*, 95–103.

Adan, A., Natale, V., Caci, H., & Prat, G. (2010). Relationship between circadian typology and functional and dysfunctional impulsivity. *Chronobiology International*, *27*, 606–619.

Anderson, C., & Platten, C. R. (2011). Sleep deprivation lowers inhibition and enhances impulsivity to negative stimuli. *Behavioral Brain Research, 217*, 463–466. doi:10.1016/j.bbr.2010.09.020

Chee, M. W. L., Parimal, S., Tan, J. C., & Zagorodnov, V. (2010). Sleep deprivation and its effect—Selective attention. *Neuroimage, 49*, 1903–1910.

Czeisler, C. A., Walsh, J. K., Roth, T., Hughes, R. J., Wright, K. P., Kingsbury, L., . . . Dinges, D. F. (2005). Modafinil for excessive sleepiness associated with shift–work sleep disorder. *The New England Journal of Medicine*, *353*, 476–486. doi:10.1056/NEJMoa041292

Dahl, R. E. (2005). Sleep, learning, and the developing brain: Early-to-bed as a healthy and wise choice for school-aged children. *Sleep, 28*, 1498–1499.

Dinges, D. F., & Kribbs, N. B. (1991). Performing while sleepy: Effects of experimentally-induced sleepiness. In T. H. Monk (Ed.), *Sleep, sleepiness and performance* (pp. 97–128). New York, NY: Wiley.

Dinges, D. F., Maislin, G., Mullington, J. M., & Van Dongen, H. P. A. (2003). The cumulative cost of additional wakefulness: Dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. *Sleep, 26*, 117–226.

Dinges, D. F., & Van Dongen, H. P. A. (2005). Sleep, circadian rhythms, and psychomotor vigilance. *Clinical Sports Medicine, 24*, 237–249.

Doran, S. M., Van Dongen, H. P. A., & Dinges, D. F. (2001). Sustained attention performance during sleep deprivation: Evidence of state instability. *Archives Italiennes de Biologie*, *139*, 253–267.

Ellenbogen, J. M., Payne, J. D., & Stickgold, R. (2005). The role of sleep in declarative memory consolidation: Passive, permissive, active or none? *Current Opinion in Neurobiology*, *16*, 716–722. doi:org/10.1016/j.conb.2006.10.006

Gasol, N., Tzischinsky, O., & Lufi, D. (2006). *The effect of sleep-wake cycles upon cognitive performance among adolescents (in Hebrew)*. Unpublished manuscript.

Goel, N., Rao, H., Durmer, J. S., & Dinges, D. F. (2009). Neurocognitive consequences of sleep deprivation. *Seminars in Neurology, 29*, 320–339. doi:10.1055/s-0029-1237117

Harrison, Y., & Horne, J. A. (2000). The impact of sleep deprivation on decision making: A review. *Journal of Experimental Psychology: Applied, 6*, 236–249. doi:10.I037//1076-8O8X.6.3.236

Horne, J. A., & Ostberg, O. (1976). A self assessment questionnaire to determine Morningness—Eveningness in human circadian rhythms. *International Journal of Chronobiology*, *4*, 97–110.

Huber, R., Ghilardi, M. F., Massimini, M., & Tononi, G. (2004). Local sleep and learning. *Nature, 430*, 78–81.

Johnson, A. L., Brown, K., & Weaver, M. T. (2010). Sleep deprivation and psychomotor performance among night-shift nurses. *Journal of American Association of Occupational Health, 58*, 147–154.

Lufi, D., & Fichman, N. (2012). Development and use of computerized test, MATH-CPT, to assess attention. *Perceptual and Motor Skills*, *114*, 59–74.

Lufi, D., Tzischinsky, O., & Hadar, S. (2011). Delaying school starting time by one hour: Some sffects on attention levels in adolescents. *Journal of Clinical Sleep Medicine, 7*, 137–143.

Owens, J. A. (2009). A clinical overview of sleep and attention-deficit/hyperactivity disorder in children and adolescents. *Journal of the Canadian Academy of Child and Adolescent, 18*, 92–102.

Peigneux, P., Laureys, S., Fuchs, S., Collette, F., Perrin, F., Reggers, J., . . . Aerts, J. (2004). Are spatial memories strengthened in the human hippocampus during slow wave sleep? *Neuron, 44*, 535–545.

Stickgold, R. (2005). Sleep dependent memory consolidation. *Nature, 437*, 1272–1278. doi:10.1038/nature04286

Stickgold, R., & Walker, M. P. (2008). Sleep-dependent memory consolidation and reconsolidation. *Sleep Medicine*, *8*, 331–333. doi:10.1016/j.sleep.2007.03.011

Talbot, L. S., McGlinchey, E. L., Kaplan, K. A., Dahl, R. E., & Harvey, A. G. (2010). Sleep deprivation in adolescents and adults: Changes in effect. *Emotion, 10*, 831–841.

Taras, H., & Potts-Datema, W. (2005). Sleep and student performance at school. *Journal of School Health*, *75*, 248–259.

Walker, M. P., & Stickgold, R. (2004). Sleep-dependent learning and memory consolidation. *Neuron, 44*, 121–133.

Westensten, N. J., Belenky, G., Kautz, M. A., Thorne, D. R., Reichardt, R. M., & Balkin, T. J. (2002). Maintaining alertness and performance during sleep deprivation: Modafinil versus caffeine. *Psychopharmacology, 159*, 238–247. doi:10.1007/s002130100916

Zomer, J., Peled, R., Rubin, A., & Lavie, P. (1985). Mini-sleep questionnaire (MSQ) for screening large populations for EDS complaints. In W. P. Koella (Ed.), *Sleep* (pp. 467–470). Basel: Krager.