

HOSTED BY



ELSEVIER

Available online at www.sciencedirect.com

ScienceDirect

www.elsevier.com/locate/ssci

The relationship between self-reported sleep quality and reading comprehension skills

Stephanie K. Ellis^a, Jeffrey J. Walczyk^b, Walter Buboltz^{b,*}, Victoria Felix^b

^aHouston Baptist College, United States

^bLouisiana Tech University, United States

ARTICLE INFO

Article history:

Received 1 September 2014

Received in revised form

8 November 2014

Accepted 8 December 2014

Available online 24 December 2014

Keywords:

Sleep

Memory

Verbal efficiency

Reading comprehension

ABSTRACT

Inadequate sleep undermines many cognitive functions, including memory, concentration, and attention, which are vital in everyday activities. We hypothesized that poor quality or shorter sleep length may impair reading-related skills, resources, and outcomes, specifically verbal working memory span, verbal efficiency, and reading comprehension. Contrary to the hypotheses, neither short sleep length nor self-reported sleep quality were related to reading skills performance. However, longer sleep times were significantly related to lower verbal efficiency, and participants with the poorest sleep quality fared significantly better on the reading comprehension task than participants with moderate sleep quality. Given the paucity of research examining sleep and reading specifically, as well as these surprising data, more research in this area is warranted.

© 2014 Brazilian Association of Sleep. Production and Hosting by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/3.0/>).

1. Introduction

The National Sleep Foundation (NSF), in its 2005 “Sleep in America” poll, noted that 40% of Americans reported getting fewer than seven hours of sleep per night on weekdays, with an average sleep length for adults on weekdays of 6.9 h per night. Additionally, when measuring sleep habits, results indicated that only 49% of participants reported having “a good night’s sleep” almost every night [27]. Furthermore, there are some variations in sleep quality demographically; women reported needing more sleep than men (6.8 h vs. 6.2 h) and older adults were more likely to report often having a good night’s sleep (38% of 18–29 year olds vs. 60% of those 65 and older) [27]. In subsequent press releases, the NSF concluded that inadequate sleep contributes to vehicular accidents, work tardiness, absenteeism, and

relationship problems [28]. However, a mere 22% percent reported getting less sleep than they needed to “function their best” [27]. Overall, this suggests that many Americans are not aware of their sleep needs, sleep deficiency, or daytime deficits in functioning due to inadequate sleep.

College students represent an important and interesting minority of adults in sleep research. College students tend to report sleep quality that is similar to that of older adults (ages 30–94), with 60% of college students reporting poor sleep quality, and 56% of older adults reporting poor sleep quality [27]. Interestingly, college students reported more difficulties than the general adult population in such areas as having difficulty falling asleep, morning tiredness, and waking too early (Buboltz et al.). Further, in the last 30 years, college students’ median sleep length has declined by more than an hour, from 7.75 h in

*Correspondence to: Department of Psychology and Behavioral Sciences, Louisiana Tech University, PO Box 10048, Ruston, Louisiana 71272, United States.

E-mail address: Buboltz@latech.edu (W. Buboltz).

1969 to 6.65 h in 2001 [18]. These findings indicate that the college population may be of particular value in examining sleep length and quality as they pertain to other functions, such as cognitive skills.

1.1. Sleep quality

Inadequate sleep can take on many forms, including restricted sleep length, poor sleep quality, and the impact of sleep disorders. Restricted sleep may take the form of sustained deprivation (i.e., one or more full night's sleep deprivation) or a limited quantity of sleep each night (e.g., 6 or fewer hours per night for several nights). Poor sleep quality is a broad label for a range of sleep issues, including both qualitative and quantitative aspects [7]. These include such objective characteristics as sleep latency or number of awakenings, as well as subjective qualities like restfulness or perceived daytime functioning. Sleep length or restriction is often one component of sleep quality. Thus, *poor sleep quality* can indicate a variety of symptoms which include disturbed or unsatisfactory sleep; it is typically operationally defined as a high score on a measure of overall sleep quality.

1.2. Poor sleep quality and cognitive impairment

A large body of research demonstrates that poor sleep quality affects a multitude of cognitive abilities. Most of this research examines the effects of sleep restriction or deprivation on cognitive functioning; a considerably smaller amount looks at other forms of poor sleep quality, such as daytime sleepiness or the symptoms associated with sleep disorders.

Sleep restriction and cognitive impairment. The cognitive functions impaired by a lack of sleep are numerous. Because of the potential danger, the impairment to driving ability due to inadequate sleep (e.g., [6]) is one of the most often studied cognitive deficits. However, driving involves multiple cognitive skills that are affected by sleep and are relevant to other activities. For example, Kim, Lee, and Kim [22] found deficits in motor and rhythm functions, receptive and expressive speech, memory, and complex verbal and arithmetic functions when administering a neurological battery and selected subtests (calculation and digit-span) of the Wechsler Adult Intelligence Scale. Additional cognitive deficits resulting from inadequate sleep are decision making, innovation, plan revision, concentration, and effective communication [17], which are important skills for many areas of life. Further, Taylor and McFatter [42] discovered that time estimation, along with immediate and delayed recall, are negatively affected by lack of sleep. Other notable deficits related to insufficient sleep are sustained attention [21], cognitive vigilance [1], and tasks utilizing cognitive flexibility [48].

Ratcliff and Van Dongen [32] explain that multiple aspects of cognitive functioning are impacted by sleep deprivation, including impairments in central processing and attentional arousal. Furthermore, Van Dongen et al. [44] demonstrated that restriction of sleep to six hours per night or less for several days produced cognitive deficits equivalent to two full nights of sleep deprivation. This indicates that a great deal of the cognitive impairments seen in total sleep deprivation research may apply to the large number of individuals with

restricted sleep patterns [1]. As sleep length is an important factor in sleep quality and most sleep disorders, research on sleep restriction may be applicable to individuals with poor sleep quality and sleep disorders as well. These findings make research on the cognitive effects on sleep restriction even more applicable to the general population.

Poor sleep quality and cognitive impairment. Compared to many studies focused on the negative effects of sleep deprivation, the few studies focused on poor sleep quality have shown similar deleterious effects on occupational and educational functioning. For example, Doi et al. [14] discovered that poor sleep quality in Japanese workers was associated with more occupational problems related to workers' health, safety, and productivity. Similar results were found with a large group of Japanese nurses. Nurses who exhibited excessive daytime sleepiness had more occupational accidents such as needlestick injuries [40]. Further, Canadian researchers found that college students carrying a full course load with poor sleep quality had worse performance on academic measures than similar students with good sleep quality [19]. Though this research is limited, measuring sleep quality, rather than just sleep length, may be especially important. Evidencing this, Semler and Harvey [39] found that individuals' perception of how they slept, even when based on false information, significantly impacted daytime functioning.

Sleep disorders, such as insomnia and sleep apnea, are by definition associated with sleep restriction and/or poor sleep quality (American Psychiatric Association, Diagnostic and Statistical Manual of Mental Disorders, 5th edition, [2]). Thus, the relationship between poor sleep and cognitive impairments can be further elucidated by examining research on sleep disorders. In a meta-analysis, Fortier-Brochu et al. [15] found support for a distinctive pattern of cognitive impairment in individuals with insomnia; working memory, episodic memory, and executive functioning were negatively affected. Narcoleptic individuals demonstrated cognitive impairments in alertness [38] as well as in attention and memory [16]. Sleep apnea, a form of breathing-related sleep disorder, can negatively impact several cognitive functions, including general intellectual functioning, attentional functioning, memory and learning abilities, executive functions, and motor performance [11]. Some cognitive tasks, such as selective attention, are affected by multiple disorders including insomnia, narcolepsy, and sleep apnea [38].

1.3. Poor sleep quality and cognitive Abilities related to reading

Central to the present study are three specific cognitive abilities integral to reading: verbal working memory, verbal efficiency, and reading comprehension. In a general sense, working memory is a "...a limited capacity system, which temporarily maintains and stores information, [and] supports human thought processes by providing an interface between perception, long-term memory and action" ([3], p.829). In reading, it is the ability to retain verbal information in consciousness as text in encoded [23]. Verbal working memory capacity undergirds the encoding and integration of text-based propositions within and across sentences of a passage [10]. Those with larger capacities, for instance, are most likely

to recall “Mary” as the referent on encountering the pronoun “she” sentences later [47]. Verbal efficiency is a construct denoting the level of automaticity of low level decoding-related processes of reading, particularly word identification and lexical-semantic access [30]. Finally, reading comprehension has been defined and measured in many ways. Common to most definitions is that comprehension concerns the extent that readers understand and remember what has been read [23,29]. Since comprehension is the goal of most readers [33], it is legitimate the focus of researchers interested in how sleeplessness might undermine reading performance.

Sleep quality and working memory. Memory and attention are two cognitive systems affected by sleep. Because working memory is tied to selective attention, it may be especially affected by poor sleep. In a brain imaging study, participants had decreased brain activity and decreased performance scores on a working memory task after 30 h total sleep deprivation than when they were well rested [25]. Those suffering from sleep apnea, a breathing-related sleep disorder, demonstrated specific working memory impairments in a study examining multiple types of memory [26]. Additionally, Varkevisser [45] showed that insomniacs had deficits in working memory, among other performance impairments, compared to healthy controls.

1.4. Sleep quality and verbal efficiency

We were unable to locate any studies to date that have examined the specific relationship between *verbal efficiency* and sleep quality. However, other findings from research on sleep and cognitive impairment suggest that skills underlying verbal efficiency in reading may be affected. For example, attention may be important for verbal efficiency and is shown to be negatively affected by poor sleep [16,24]. Because this specific area has not been researched, this study could provide an entry into an important avenue in research on cognition and sleep. Even simple processes, such as visual perception, are both impaired by lack of sleep [37] and necessary for verbal efficiency. However, some recent data regarding lexical access, the ease with which people recognize words, has indicated that no impairment is seen after sleep restriction, while automatic lexical processing (recognizing words without mental effort) is increased after sleep restriction [41]. These skills are similar to verbal efficiency. Thus, the effect of poor sleep on verbal efficiency is uncertain.

1.5. Sleep quality and reading ability/comprehension

Because cognitive functions such as memory, concentration, attention, vigilance, and cognitive flexibility are used in everyday work and school activities such as reading, we hypothesized that inadequate sleep may impair reading comprehension. Very few studies have specifically examined the effects of sleep on reading performance. In a small scale study, Webb [49] found that older adults who were sleep deprived retained reading skills such as reading rate and comprehension, though only half were able to sustain non-deprived reading performance. A recent study including school-aged children found that sleep disturbances, especially difficulty falling asleep, staying asleep, and sleeping too

much, were negatively related to a measure of school achievement which included reading ability and reading comprehension among other variables [4]. These findings indicate that there may be a relationship between sleep and reading ability. The paucity of research in this area, the pervasiveness of inadequate sleep in society, and the fundamental importance of reading ability for the learning of both children and adults make the focus of the present research timely and of theoretical importance and practical significance to scientists and educators, respectively.

1.6. The present study

This study examined subjective sleep experiences, both immediately (last night's sleep) and short term (last month's sleep) among college students. Additionally, it examined reading skills, including word naming, semantic encoding, working memory, reading speed, and reading comprehension. We hypothesized that participants with poorer subjective sleep experience would have poorer reading performance in all areas. In particular, the following two hypotheses were tested.

H1. Subjective sleep quality will be related to reading skills performance (working memory, verbal efficiency, and reading comprehension).

H2. Hours slept will be positively correlated with reading skills performance.

2. Method

2.1. Participants

The sample consisted of 138 college students (42.8% male) aged 18–48 ($M=19.96$, $SD=4.02$) from a mid-sized Southern University. College students were the population sample due to their known high incidence of sleep difficulty [5]. The sample was 71.7% Caucasian, 19.6% African American, 8.7% Other (Hispanic/Latino, Asian American, Other). Freshmen composed 59.4% of the sample; 19.6% were sophomores; 10.1% were juniors; and 5.8% were seniors (5.1% did not give this information). The mean grade point average reported was 3.05 ($SD=.504$). The students were recruited primarily from introductory psychology courses.

2.2. Instruments

Pittsburgh Sleep Quality Index. This instrument [7] is a retrospective self-report measure of sleep quality and disturbance over the past month. The PSQI contains 19 items which include forced choice Likert-type questions, as well as items that request qualitative information from the participants such as number of minutes to fall asleep, usual bedtime and wake time, and number of hours slept. The items address 7 components: sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbance, use of sleep medications, and daytime dysfunction. The range of this instrument is from 0 to 21; a score greater than five indicates poor sleep quality. Using these criteria, the original

instrument had a sensitivity of 89.6% and specificity of 86.5% in distinguishing good and poor sleepers. It was originally designed for use with clinical adult populations, but has been used with non-clinical populations as well. The PSQI has an overall internal consistency of .83.

Sleep Quality Index (SQI). This eight item self-report measure [43] is intended to distinguish poor sleepers from good sleepers with scores ranging from 0 to 16. Items are scored zero, one, or two with higher scores indicating poorer sleep quality, and a score greater than nine identifying poor sleepers. A random adult sample from a non-clinical population was used to obtain an internal consistency for the measure of .73 for males and .75 for females [43].

Lexical access task. Word naming latency measured lexical access, that is, the ability to recognize words efficiently [30]. The 20 words used by Walczyk [46] were adopted for the word naming portion of this study. Each word was presented, individually, at the center of a computer screen. The computer was fitted with a voicekey microphone, and the participant was instructed to say the word in a loud voice as quickly as possible. Once the word was named, there was a 2 s inter-stimulus interval (clear screen) before the next stimulus was presented. Accuracy data were not collected for this task because past research has shown that error rates are low. Accordingly, there is little variability in accuracy [46]. The summary data collected from this task for each participant was the median length of time across the 20 words in milliseconds between the presentation of the word and its utterance.

Semantic memory access task. The efficiency with which information is accessed from semantic memory was assessed by having the participant decide as quickly as possible if two nouns, presented at the same time on the computer monitor, belong to the same category [8,9]. Walczyk's [46] semantic categories (furniture, food, sports, plants, animals, and clothing) were used and twenty noun pairs were produced, drawn evenly from the 6 categories. Ten of the pairs belonged to different categories. The other ten belonged to the same category. After reviewing the six categories, experimenters asked the participant to say "same" into the microphone if the two nouns belong to the same category or say "different" if the words belong to different categories. Following the participant's response, the screen was cleared. There was a two second inter-stimulus interval. Again, accuracy data on this task were not collected due ceiling effects [46]. Response times were measured to the millisecond level of precision, and the median across the 20 items summarize each participant's performance.

Working memory task. Verbal working memory span was measured with Walczyk's [46] variation of the memory probe procedure of Perfetti and Goldman [31]. Twenty five pairs of thematically related sentences of varying lengths were presented. All words were individually blocked out with "X's" and the participant initiated the presentation of each word in turn using the space bar. When the space bar was pressed, the next word was "uncovered" and the previous word was replaced again by "X's." When the participant finished reading, the screen was cleared. Then, following a 2 s interval, a probe word from the sentence pair was presented. The participant was required to say from memory the word that

came right after the probe in the sentence pair as quickly as possible into the voicekey microphone. Latency was measured to the nearest millisecond. The participant was then instructed to type the word they had uttered (i.e., one they believe came after the probe word) into the computer where it was stored in a data file. The median of the 25 response times summarized latency for each participant. Accuracy, which was scored by a graduate research assistant after data collection, had a range from 0 to 25. This measure has been shown to be highly correlated with reading comprehension and other reading skill measures, indicating convergent and criterion validity [31,46,47].

Reading comprehension task. Four passages, on a variety of topics, were presented in random order to the participants on a computer screen, each 12 sentences in length. The passages, also adopted from Walczyk [46], had Flesch Kincaid Reading levels of 9.0, 11.0, 11.5, and 12.0, appropriate for college students. Participants read each passage at their leisure. When finished, the screen was cleared and the comprehension task followed.

A sentence verification technique (SVT) test was the measure of comprehension for each passage [35]. Superior in many ways to multiple-choice tests, SVT tests required readers to decide (yes/no) if the sentence presented on the computer screen had the same meaning as a sentence from the passage. There were 16 test items for each 12 sentence passage; 4 Originals were taken verbatim from the passage; 4 Paraphrases express the same meaning of sentences of the passage but in different words; 4 Meaning Changes were sentences of the original whose meaning has been radically changed by adding a word or two. Lastly, Distractors were sentences that plausibly could have been in the passage but were not. The correct responses for the former two categories was "yes", for the latter two categories "no." Summing across passages, total comprehension accuracy had a range from 0 to 64.

SVT tests require readers to recognize rather than recall information over the entire passage. Thus, they are more sensitive memory measures than passage recall or multiple-choice test items [35]. SVT tests also have many desirable psychometric properties. For instance, test performance is sensitive to individual differences in skill level and to passage differences in readability [35]. Also, they measure passage level comprehension, not just comprehension at the sentence level [36]. Finally, SVT test performance has criterion validity, specifically in predicting course grades in college courses [34].

2.3. Procedure

Informed consent was obtained from participants and their names were recorded separately to have a record of participation. Participants were individually tested in a small, quiet, well lit room. Each of the reading skills tasks was presented in random order. Reading skills were measured using a lexical access task, semantic memory task, verbal working memory task, and reading comprehension task. Each task had written instructions as well as a prompt to call for the experimenter so that instructions could be given orally. A few practice items always preceded tests items to familiarize participants with each of the reading tasks. Following the

reading tasks, participants completed the PSQI, SQI, and demographic form.

The sleep questionnaires were presented after the reading skills tasks to avoid a participant bias effect on the reading tasks. Research by Semler and Harvey [39] indicates that even inaccurate knowledge about quality of sleep affects participant daytime functioning. Thus, we wanted to avoid influencing the participants' performance on the reading tasks by pre-focusing their attention on sleep quality. Each session lasted approximately one hour.

3. Results

Table 1 provides descriptive statistics for each measure. There were no significant gender differences on any measure, thus the data has been collapsed into one group for further analysis. Pearson correlations and a MANOVA were used to evaluate these data. A factor analysis, followed by Varimax orthogonal rotation, was also conducted on the lexical access and semantic latency measures per Walczyk's [46] recommendation. A single factor emerged with both variables loading positively on it. It is referred to hereafter as "verbal efficiency."

3.1. Hypothesis 1

Table 2 provides Pearson correlations between the two measures of sleep quality and each measure of reading skill. Contrary to Hypothesis 1, no correlation between sleep quality and reading skill was found.

Table 3 provides the results of a MANOVA, using sleep quality scores on the PSQI and SQI as independent variables and total reading comprehension, working memory, and verbal efficiency as dependent variables. There was a statistically significant difference between medium sleepers and poor sleepers as grouped by the SQI, $F(8, 252)=2.061, p<.05$. Post hoc tests (see Table 4) utilizing Tukey's Honestly Significant Difference test revealed that poor sleepers performed better on total reading comprehension than medium quality sleepers. These results do not support Hypothesis 1. No other statistically significant differences were found.

3.2. Hypothesis 2

Table 5 provides Pearson correlations between hours slept (estimated for the last month and hours slept the night before) and reading skill. Contrary to Hypothesis 2, no correlation was found between hours slept (last night or last month) with total reading comprehension or working

memory. However, both measures of sleeping time were significantly positively correlated with verbal efficiency. This indicates that the longer a participant slept, the longer it took them to retrieve and produce verbal information. This is the opposite direction than was expected.

4. Discussion

This study was designed to explore the effects of sleep quality on reading skills, specifically reading comprehension. The expectation, based on previous research, was that poor sleep quality and short length of sleep would negatively affect performance on reading tasks. Most of the results indicate that there were no differences in the reading comprehension or working memory capacities of good and poor sleepers. However, two significant results, contrary to our expectations, were found. When measured by the Sleep Quality Index (SQI), participants with poor sleep quality performed better on total reading comprehension than those with moderate sleep quality. Additionally, while we expected that poor sleep would be associated with poor verbal efficiency, the results show the opposite trend, at least in terms of sleep length.

We suspect that the surprising results regarding reading comprehension may be linked to natural compensatory mechanisms. Compensatory effort can temporarily offset the effects of sleep loss on tasks of short duration [17,20]. For example, Drummond et al. [13] found that as tasks were increased in difficulty, participants performed equally well on tasks after sleep deprivation as they did after a regular night's sleep. The most interesting findings were that brain imaging results showed increased activity in several areas of the brain after sleep deprivation, which the researchers suggest indicates compensatory mechanisms at work. It could be that the findings of this study are related to these compensatory mechanisms; this is a possible explanation for the finding that subjects with poor sleep quality and short sleep length performed better on some tasks. However, the findings of this study cannot be explained entirely by these processes. If these particular results were replicated, it would contradict some of what is known about the effect of sleep quality and sleep deprivation on cognitive functioning. Thus, further research should examine the mechanisms of sleep and cognitive function as well as continued research regarding compensatory mechanisms for overcoming, at least temporarily, a lack of sleep.

The results concerning verbal efficiency may possibly be explained by examining the difference between controlled and automatic processes. Cognitive processes which require sustained attention are often negatively affected by restricted sleep; the relationship between attention necessary for a task and the degree to which that task is negatively affected by sleep loss is positive [20]. If the impairment in these tasks is primarily due to the impairment of sustained attention, automatic processing tasks (tasks that do not require sustained attention) would not be affected. Further, Swann et al. [41] suggest that automatic processing becomes more important to word recognition after partial sleep loss, which is an important component to verbal efficiency. These findings are consistent with Swann et al.'s findings that automatic lexical

Table 1 – Descriptive Statistics.

Variable	M	SD	N
Lexical access	.805	.338	138
Semantic latency	1.302	.333	138
Working memory accuracy	16.203	3.515	138
Total comprehension	42.645	5.870	138
Sleep quality – PQSI	6.60	3.290	138
Sleep quality – SQI	4.64	3.400	135

Table 2 – Pearson correlations of sleep quality and reading skill.

Sleep quality	Total comprehension	Verbal efficiency	Working memory
PSQI	.039	–.143	.010
SQI	.106	–.153	.128

Table 3 – MANOVA table for sleep quality (SQI andpsqi) and reading skill.

Variable	MANOVA F (6, 254)	ANOVA		
		Working memory F (5, 129)	Verbal efficiency F (5, 129)	Total comprehension F (5, 129)
Sleep Quality (SQI)	2.393*	1.274	.139	5.229**
Sleep Quality (PSQI)	1.110	.377	.255	1.742
SQI × PSQI	1.130	.209	.019	2.777

Note: Multivariate F ratios were generated from Wilks' Lambda statistic.

* $p < .05$.

** $p < .01$.

Table 4 – Mean scores on measures of reading skills as a function of sleep quality.

Reading skill	Sleep quality group					
	Poor sleep		Moderate sleep		Good sleep	
	M	SD	M	SD	M	SD
Working Memory	16.79	3.24	16.56	3.38	15.63	3.75
Verbal Efficiency	–.253 _a	.694	–.036 _a	.939	.109	1.143
Total Comprehension	45.16	6.78	41.66	5.42	42.86	5.50

Note: Means in a row sharing subscripts are significantly different at $p < .05$.

Table 5 – Pearson correlations between sleeping time and reading skill.

Hours slept	Total comprehension	Verbal efficiency	Working memory
Last Month	–.073	.233**	–.073
Last Night	–.070	.204*	–.035

* $p < .05$.

** $p < .01$.

processing is improved following sleep loss. Further research on these phenomena is needed.

The other results of this study, in which no significant differences were found between or among the sleep groups for most tasks, may be explained by the nature of this study. The tasks included in this study took about one hour to perform. In addition, all material involving memory was tested within a few seconds to a few minutes after its initial presentation. We suspect that participants were able to maintain at least moderate levels of functioning because this task was brief. It may be that the deleterious cognitive effects of poor sleep may not be evident under such conditions. Thus, the results may not be highly generalizable. The possibility exists that poor sleep affects individuals more over a longer active period of time (e.g., the school day or

work day) or when they are not able to maintain their focus (e.g., when they are not highly motivated to do well on an activity they know will last less than an hour). This is further suggested by data that indicates that levels of arousal, specifically wakefulness and vigor, affect reading performance [12].

Another possibility is that, while poor sleep may have negative effects on some cognitive processes, such as working memory, it may have neutral or positive effects on other processes, such as verbal efficiency. This may make the study of complex processes like reading, which incorporate many lower level processes, difficult to study. This may be an explanation for studies in which conflicting or few significant results are observed. Further research into the specific effects of poor sleep quality on specific cognitive skills such as

reading needs to be conducted, possibly under more naturalistic testing conditions.

This study was limited in several ways. Firstly, a larger sample size may have had sufficient power to produce more significant results. A larger number of poor sleepers would have made for more equal groups and perhaps better results from statistical analyses. Additionally, the environment in which the reading skill testing was performed fluctuated in temperature and was sometimes unavoidably interrupted by nearby classrooms. These changes may have impacted individual performance and muddled the results. The use of additional reading comprehension measures may also produce more significant findings. Upon examination, correlations among the four SVT subtests, each with a range from 0 to 16, fell in the range of .17-.46. Other choices of reading comprehension might be added in future research with greater internal consistency. Also, the use of different kinds of sleep measures may be beneficial. Retrospective subjective self-reports of sleep quality, despite the findings of Semler and Harvey [39], may not assess all important aspects of sleep quality essential to daytime cognitive functioning. Finally, the effects of poor sleep quality on reading skill may not be evident after such a short time (one hour or so). A study which examined the comprehension and memory for stimuli over a much longer time interval (e.g., material presented in class and then remembered for a test) may produce different results.

Given the sleeplessness of many Americans and what is known regarding its negative impact on wellbeing and functioning, even more research in this area is needed. Of particular importance to our education- and occupation-focused culture are the potentially deleterious effects of inadequate sleep on cognitive performance. Future research which replicates or expands on the results of this study while overcoming its limitations is warranted. Along with this, other types of research, such as qualitative or experimental designs, may be particularly valuable in uncovering the mechanisms behind any negative outcomes of poor sleep quality.

REFERENCES

- [1] Altena E, Van Der Werf YD, Strijers RM, Van Someren EW. Sleep loss affects vigilance: effects of chronic insomnia and sleep therapy. *J Sleep Res* 2008;17:335-43. . <http://dx.doi.org/10.1111/j.1365-2869.2008.00671.x>.
- [2] American Psychiatric Association. *Diagnostic and statistical manual of mental disorders*, 5th ed.. Washington, DC: Author; 2013.
- [3] Baddeley A. Working memory: looking back and looking forward. *Nat. Rev.: Neurosci.* 2003;4:829-39.
- [4] Bruni O, Ferini-Strambi L, Russo PM, Antignani M, Innocenzi M, Ottaviano P, et al. Sleep disturbances and teacher ratings of school achievement and temperament in children. *Sleep Med* 2006;7(1):43-8.
- [5] Buboltz WC, Brown F, Soper B. Sleep habits and patterns of college students: a preliminary study. *J Am Coll Health* 2001;50(3):131-5.
- [6] Bueno AV. Sleep deprivation and driving performance. *Vigilia-Sueno* 2002;14:S43-6.
- [7] Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res* 1989;28:193-213.
- [8] Chabot RJ, Miller TJ, Juola JF. The relationship between repetition and depth of processing. *Mem Cogn* 1976;4:677-82.
- [9] Chabot RJ, Petros TV, McCord G. Developmental and reading ability differences in accessing information from semantic memory. *J Exp Child Psychol* 1983;35:128-42.
- [10] Daneman M, Carpenter PA. Individual differences in integrating information between and within sentences. *J Exp Psychol: Learn, Mem, Cogn* 1983;9:561-84.
- [11] Decary A, Rouleau I, Montplaisir J. Cognitive Deficits associated with sleep apnea syndrome: A proposed neuropsychological test battery. *Journal of Sleep Research & Sleep Medicine* 2000;23:369-81.
- [12] Dickman SJ. Dimensions of arousal: wakefulness and vigor. *Hum Factors* 2002;44(3):429-42.
- [13] Drummond S,P, Brown GG, Salamat JS, Gillin JC. Increasing task difficulty facilitates the cerebral compensatory response to total sleep deprivation. *Sleep* 2004;27(3):445-51.
- [14] Doi Y, Minowa T, Tango T. Impact and Correlates of Poor Sleep Quality in Japanese White-collar Employees. *Journal of Sleep and Sleep Disorders Research*, 2003;26:467-71.
- [15] Fortier-Brochu É, Beaulieu-Bonneau S, Ivers H, Morin CM. Insomnia and daytime cognitive performance: a meta-analysis. *Sleep Med Rev* 2012;16:83-94. . <http://dx.doi.org/10.1016/j.smr.2011.03.008>.
- [16] Hansen D, Vandenberg B. Cognitive effects of sleep apnea and narcolepsy in school age children. *Sleep Hypn* 2001;3(2):73-80.
- [17] Harrison Y, Horne JA. The impact of sleep deprivation on decision making: a review. *J Exp Psychol: Appl* 2000;6(3):236-49.
- [18] Hicks RA, Fernandez C, Pellegrini RJ. The changing sleep habits of university students: an update. *Percept Motor Skills* 2001;93(3):648.
- [19] Howell A, Jahrig J, Powell R. Sleep Quality, Sleep Propensity and Academic Performance. *Perceptual and Motor Skills*, 2004;99:525-35.
- [20] Jennings JR, Monk TH, van der Molen MW. Sleep deprivation influences some but not all processes of supervisory attention. *Psychol Sci* 2003;14:473-9.
- [21] Jung CM, Ronda JM, Czeisler CA, Wright KR. Comparison of sustained attention assessed by auditory and visual psychomotor vigilance tasks prior to and during sleep deprivation. *J Sleep Res* 2011;20:348-55. . <http://dx.doi.org/10.1111/j.1365-2869.2010.00877.x>.
- [22] Kim DJ, Lee HP, Kim MS. The effect of total sleep deprivation on cognitive functions in normal adult male subjects. *Int J Neurosci* 2001;109(1-2):127-37.
- [23] Kintsch W. *Comprehension: a paradigm for cognition*. New York: Cambridge University Press; 1998.
- [24] McCarthy M, Waters W. Decreased attentional responsivity during sleep deprivation: Orienting response latency, amplitude, and habituation. *Sleep: Journal of Sleep Research & Sleep Medicine*, 1997;20:115-23.
- [25] Mu Q, Nahas Z, Johnson KA, Yamanaka K, Mishory A, Koola J, et al. Decreased cortical response to verbal working memory following sleep deprivation. *Sleep: J Sleep Res Sleep Med* 2005;28(1):55-67.
- [26] Naëgelé B, Launois SH, Mazza S, Feuerstein C, Pepin JL, Lévy P. Which memory processes are affected in patients with obstructive sleep apnea? An evaluation of 3 types of memory. *Sleep: J Sleep Res Sleep Med* 2006;29(4):533-44.
- [27] National Sleep Foundation. 2005 sleep America poll. (http://www.sleepfoundation.org/_content/hottopics/Sleep_Segments.pdf); 2005 [retrieved 9.09.05].

- [28] National Sleep Foundation. Sleep facts and stats. (<http://www.sleepfoundation.org/hottopics/index.php?secid=9&id=34>); n.d. [retrieved 9.09.05].
- [29] Perfetti C. Cognitive research can inform reading education. *Journal of Research in Reading*, 1995;18:106-15.
- [30] Perfetti CA. Reading ability. New York: Oxford University Press; 1985.
- [31] Perfetti CA, Goldman SR. Discourse memory and reading comprehension skill. *J Verbal Learn Verbal Behav* 1976;15(1):33-42.
- [32] Ratcliff R, Van Dongen HA. Sleep deprivation affects multiple distinct cognitive processes. *Psychon Bull Rev* 2009;16:742-51, . <http://dx.doi.org/10.3758/PBR.16.4.742>.
- [33] Rayner K, Pollatsek A. The psychology of reading. Englewood Cliffs: Prentice Hall; 1989.
- [34] Royer JM, Abranovic WA, Sinatra GM. Using entering reading comprehension performance as a predictor of course performance in college classes. *J Educ Psychol* 1987;79:19-26.
- [35] Royer JM, Hastings CN, Hook C. A sentence verification technique for measuring reading comprehension. *J Read Behav* 1979;11:355-63.
- [36] Royer JM, Lynch DJ, Hambleton RK, Bulgarelli C. Using the sentence verification technique to assess the comprehension of technical text as a function of subject matter expertise. *Am Educ Res J* 1984;21:839-69.
- [37] Russo MB, Kendall AP, Johnson DE, Sing HC, Thorne DR, Escolas SM, et al. Visual perception, psychomotor performance, and complex motor performance during an overnight air refueling simulated flight. *Aviat, Space, Environ Med* 2005;76(7):C92-c103.
- [38] Schneider C, Fulda S, Schulz H. Daytime variation in performance and tiredness/sleepiness ratings in patients with insomnia, narcolepsy, sleep apnea and normal controls. *J Sleep Res* 2004;13(4):373-83.
- [39] Semler CN, Harvey AG. Misperception of sleep can adversely affect daytime functioning in insomnia. *Behav Res Ther* 2005;43(7):843-56.
- [40] Suzuki K, Ohida T, Kaeito Y, Yokoyama E, Uchiyama M. *Journal of Advanced Nursing*, 2005;52:445-53.
- [41] Swann CE, Yelland GW, Redman JR, Rajaratnam SM. Chronic partial sleep loss increases the facilitatory role of a masked prime in a word recognition task. *J Sleep Res* 2006;15(1):23-9.
- [42] Taylor DJ, McFatter RM. Cognitive performance after sleep deprivation: does personality make a difference? *Personal Individ Differ* 2003;34(7):1179-93.
- [43] Urponen H, Partinen M, Vuori I, Hasan J. Sleep quality and health: Description of the Sleep Quality Index. In: Peter BJH, Penzel T, Podszus T, Von Wichert P, Sleep and health risk. New York, NY: Springer; 1991. p. 555-8.
- [44] Van Dongen HPA, Maislin G, Mullington JM, Dinges DF. The cumulative cost of additional wakefulness: dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. *Sleep* 2003;26:117-26.
- [45] Varkevisser M. Chronic insomnia and performance in a 24-h constant routine study. *J Sleep Res* 2005;14(1):49-59.
- [46] Walczyk JJ. A test of the compensatory-encoding model. *Read Res Q* 1995;30:396-408.
- [47] Walczyk JJ, Wei M, Griffith-Ross DA, Goubert SE, Cooper AL, Zha P. Development of the interplay between automatic processes and cognitive resources in reading. *J Educ Psychol* 2007;99:867-88.
- [48] Walker MP, Liston C, Hobson J, Stickgold R. Cognitive flexibility across the sleep-wake cycle: REM-sleep enhancement of anagram problem solving. *Cogn Brain Res* 2002;14:317-24, . [http://dx.doi.org/10.1016/S0926-6410\(02\)00134-9](http://dx.doi.org/10.1016/S0926-6410(02)00134-9).
- [49] Webb WB. Sleep deprivation and reading comprehension. *Biol Psychol* 1986;22(2):169-72.