Kwantlen Psychology Student Journal
Issue 6, August 2024
Kwantlen Polytechnic University

Confidence in Judgement Among the Chronically Sleep-Deprived

Aidan Sammel[1]

Abstract

Research has demonstrated that acutely and chronically sleep-deprived individuals are hindered in their performance on cognitive tasks, with pronounced effects on working memory tasks (Durmer & Dinges, 2005). However, little research has been done to examine the effects of sleep deprivation on metacognitive performance. Here, we test whether chronic sleep deprivation affects calibration scores during a working memory task and whether this is dependent on whether participants complete an easy or hard task. Participants aged 18-65 (*N* = 33) completed a practice mental arithmetic task and made confidence judgments on their expected performance before completing a subsequent 10 mental arithmetic tasks. Results showed that participants were equally calibrated regardless of sleep quantity or task difficulty. These findings could suggest that people can accurately assess their cognitive performance when chronically sleep-deprived, though more research is needed to know whether these findings are accurate. The implications and limitations of the study will be discussed, and directions for future research are proposed.

---

[1] aidan.sammel@student.kpu.ca; Written for Applied Research I (PSYC 3400). This study was completed as part of a course requirement for Psychology 3400. I would like to extend a heartfelt thank you to my instructor for this course, Dr. Liudmila Jdanova, for helping me with this project, and for the recommendation for this paper to be submitted to the KPSJ.

Confidence in Judgement Among the Chronically Sleep-Deprived

The inimical effects of sleep deprivation (SD) on cognitive performance have been examined extensively in research literature. Research has indicated that both one night of lost sleep and chronic sleep deprivation lead to highly evident hindrances to cognitive performance, with explicitly pronounced effects on working memory (Baranski, 2007; c.f. Angus & Heslegrave, 1985; Wilkinson, 1965). Subjective assessments of fatigue, mood, and alertness have also been shown to be highly affected by SD (Babkoff et al., 1991; Baranski, 2007).

"Higher order" cognitive functions have been examined in relation to SD, with judgment and decision-making capabilities showing declined function after a short period of SD (Baranski, 2007; Harrison & Horne, 1998, 1999, 2000). However, in terms of higher order cognitive functions, little attention has been given to "metacognitive" ability (i.e., one's ability to monitor their performance during a given task) in relation to SD (Baranski, 2007; Baranski et al., 2002; Baranski & Pigeau, 1997; Blagrove & Akehurst, 2000; Dorrian et al., 2000).

Sleep loss is prevalent in contemporary societies, and the resulting fatigue that one experiences has important consequences~~.~~ (Coren, 1997). Most pertinently, chronic sleep loss has been previously associated with deleterious losses in productivity (Krueger, 1989). Sleep deprivation has particularly important implications for college students, as losses in student productivity are associated with low GPA, and lack of long-term academic success (Cabral et al., 2022; Chen & Chen, 2019). Thus, the ability to successfully judge one's cognitive ability in a sleep-deprived state is an important element in forming compensatory behaviors toward losses in productivity (Baranski, 2007). If metacognitive performance is inhibited in a state of chronic sleep loss, forming compensatory behaviors becomes difficult, as one may underestimate or overestimate their ability.

For college students, underestimating or overestimating one's working memory can have important implications. If one is underconfident in their ability, they may spend unnecessary cognitive resources studying information they already know, and if one is overconfident, they may spend less time studying or may engage in "overnight cramming" before a test, further contributing to their chronic sleep loss. Research has shown that chronic sleep loss in college students results in significantly lower graduation rates and harmful cognitive outcomes (Chen & Chen, 2019).

The metacognitive ability to self-monitor performance has been linked with executive functions, particularly those associated with the prefrontal cortex (PFC) (Baranski, 2007; Chee & Choo, 2004; Drummond et al., 1999, 2000; Durmer & Dinges, 2005; Harrison et al., 2000), and research has shown that cognitive tasks associated with the PFC are highly susceptible to the effects of sleep deprivation (Fernandez-Duque et al., 2000; Mazzoni & Nelson, 1998). In this case, one assumption is that the ability to self-monitor performance should be equally susceptible to SD effects as other prefrontal cognitive functions, if not more so (Baranski, 2007; Harrison & Horne, 2000).

It is also important to note that changes in performance on tasks during sleep deprivation are not necessarily the result of a change in participant effort. One study found that, in line with baseline measurements, the PFC and parietal lobes were activated in response to verbal learning following SD, but that activation in these areas was significantly reduced during a serial subtraction task following SD (Drummond et al., 2000). However, the study found that a change in effort did not explain this change in activation, as neither subjective levels of effort nor perceived task difficulty changed with SD or correlated significantly with localized changes in brain activation after SD. This may indicate that participants' metacognitive monitoring remained accurate throughout the task. If participants were underconfident in their ability to complete the task, we may have expected an increase in effort, whereas if participants were overconfident in their ability, we may have expected to see reduced effort throughout the task. Research has also indicated that even when SD individuals are aware that their performance is declining on a task, they are unable to improve their performance with increased efforts. A study by Dinges and Kribbs (1991) showed that participants could not improve their performance on a vigilance task after 64 hours of sleep deprivation despite increased efforts.

Baranski and Pigeau (1997) showed that sleep-deprived individuals can monitor their performance to a reasonable degree. Their findings were based on global assessments made at the task level (Baranski & Pigeau, 1997). Research on calibration indicates that individuals generally exhibit lower confidence in their overall estimation of the accuracy rate of their answers (global confidence) compared to the accuracy rate of their specific answers, which indicates local confidence (Liberman, 2004). Baranski (2007) later conducted a follow up study and demonstrated that among tasks that tested various cognitive abilities, each of which had various susceptibility to SD, the ability to assess accurately one’s own performance did not significantly deteriorate over a 28-hour SD period. These tasks included a working memory, perceptual comparison, and general knowledge task. An important limitation of Baranski’s study is that these participants had only been sleep-deprived for a maximum of 28 hours (acute total sleep deprivation). Expanding on this research, we would like to explore the effect that chronic partial sleep deprivation has on one’s metacognitive ability to self-monitor their cognitive performance.

According to Baranski (2007), the index used for confidence judgement is over and under confidence. Intuition judgments are considered overconfident if the subjective proportion of confidence exceeds the objective proportion of correct answers. They are considered underconfident if the reverse is true. Therefore, a negative score denotes underconfidence, and a positive score denotes overconfidence.

Another way to measure confidence judgments is calibration~~,~~ (Baranski, 2007). Calibration involves comparing actual measured scores to predicted outcomes. This method doesn't require differences between individuals in the measured attribute, as the primary focus of calibration analysis is to assess how accurate judgments are at different confidence levels. Poor calibration is achieved if the proportion of correct responses is relatively constant across the various confidence levels on tests and assessments. On the other hand, good calibration denotes a rapidly increasing function relating to confidence and judgment accuracy. In this study, we will be using calibration to measure confidence judgments.

In the present study, our objective is to replicate previous research, as well as contribute to the evidence for the basis of the metacognitive ability to self-monitor during sleep deprivation. We want to examine whether people correctly calibrate their ability while in a chronic sleep-deprived state compared to those who are not sleep-deprived.

Previous literature has indicated that people can effectively monitor their performance on various cognitive tasks after 28 hours of constant wakefulness (Baranski, 2007). In this study, the cognitive task of interest is a mental arithmetic task, which has been utilized by Baranski (2007). Mental arithmetic tasks are highly reliant on working memory and are highly sensitive to the effects of SD (Drummond et al., 1999; Zhang et al., 2022). One study found that SD affects the prefrontal cortex (PFC) and other brain regions involved in arithmetic performance. These regions include the bilateral parietal lobes, left premotor region, and lingual gyrus. (Drummond et al., 1999).

It has also been shown that motivation is a key factor in how SD affects a person's performance. If a task is new and interesting for the participant, their performance on it will be unaffected by SD. However, if the task is performed multiple times and it becomes learned, the participant will be negatively affected by the SD (Harrison & Horne, 2000). For example, after one night of SD, a well-rehearsed, 10-minute, simple reaction-time task shows deterioration in the first five minutes of the task. Thus, to minimize this loss in motivation, we will be presenting participants with a task that includes 10 trials that take 25 seconds each, for a total task time of four minutes and 10 seconds.

As opposed to the results seen in Baranski's (2007) study, we expect that chronic sleep deprivation will affect people's ability to monitor their performance on working memory tasks. Past research has demonstrated that chronically sleep-deprived participants are no less likely to make bets in high-risk situations than participants who are well-rested, suggesting impaired calibration of judgment after a period of chronic sleep debt (Fraser et al., 2013). Research has also shown that people are highly uncalibrated in their performance judgments during very difficult conceptual tasks (Kvidera & Koutstall, 2008). In our study, based on the results from Fraser's (2013) study and Kvidera & Koustall's (2008) study, we expect to see a difference in calibration between the sleep-deprived group and the well-rested group on the difficult trials, but not the easy trials. In other words, we expect that sleep-deprived participants will be less calibrated in making their confidence judgments when completing a difficult task but equally calibrated when completing an easy task.

Method

Research Methodology

We performed a quasi-experimental study using a two-way factorial ANOVA 2x2 design. Our independent variables were sleep quantity and task difficulty. Sleep had two levels: sleep-deprived and well rested, while task difficulty had two levels: easy and hard. Our dependent variable was calibration. We used Qualtrics to obtain our data online.

Participants

We used convenience sampling to obtain our participants. The study was posted online on the Kwantlen SONA system, where all KPU students were welcome to join the study and participate. After finishing the study online, they were automatically awarded 0.5% towards a qualifying course. We also posted the survey on Reddit, where people could choose to participate in the study as volunteers. Every participant had to sign a consent form before beginning the study. If they didn't sign the consent form, they were not allowed to take the study. We were able to obtain 33 participants for our study. All participants who completed the study met the inclusion criteria. Participant age ranged from 18-60 and included an approximately equal proportion of males and females. There were 11 participants in the well-rested group and 22 in the sleep-deprived group.

Measures and Instruments

Sleep deprivation. Participants were asked, on average, how many hours of sleep they got per night in the last two weeks. Options included 8 hours or more or 7 hours or less. Based on this information, they were divided into two groups: a well-rested group (8 hours or more of sleep per night on average during the last two weeks) and a chronically sleep-deprived group (7 hours or less of sleep per night on average, during the last two weeks).

Confidence levels. Confidence levels were measured on a 10-point ratio scale. Responses ranged from 0 (not confident at all) to 1 (completely confident). Intervals were set at 0.1 units.

Mental Arithmetic Task. Participants performed a mental arithmetic task. This task was adapted from Baranski (2007), and the justification for using this task is explained in length above.

Difficulty. Participants were randomly placed into an "easy task" group and a "hard task" group. Participants in both groups were given 10 trials. In each trial, participants had to give a response to 10 successive arithmetic questions. In the easy task, we presented participants with a number that flashed on the screen along with an arithmetic sign, either a +, -, x or ÷. In each easy trial, the item flashed on the screen for 3 seconds. Numbers ranged from 1-10. After the item disappeared, the screen went blank momentarily. After this brief period, a new item appeared with a new number and arithmetic sign. For the hard task, items flashed on the screen for 2 seconds, and numbers ranged from 0-100.

Calibration. Calibration represents the alignment between a subjective probability assessment indicating how likely an event is to occur and the actual empirical probability of that event occurring (Baranski, 2007). For example, if a participant indicated a subjective probability assessment of 0.5 and was correct in 5/10 of their answers, they will be perfectly calibrated in their judgment. According to (Baranski, 2007; c.f. Murphy, 1973), calibration scores are represented by a weighted squared deviation that compares the mean proportion of confidence associated with each interval and the proportion of correct responses associated with each confidence interval.

$$\frac{1}{n}\sum_{j=1}^{J} n_j(\bar{p}_j - \bar{e}_j)^2$$

Here, pj represents the mean proportion confidence in confidence interval j and ej represents the mean proportion correct in confidence interval j. Further, nj is the number of observations in confidence interval j, and n is the total number of observations. The calibration score ranges between 0.0 (optimal score) and 1.0 (the worst possible score).

Procedure

After signing the consent form, participants were asked demographic questions, as well as questions about their sleeping habits. Afterward, they were told they would be completing a mental addition task, with 10 trials. Participants were randomly assigned to and easy or hard trial, with half of participants completing 10 easy trials, and half completing 10 hard trials. Participants were told whether the trials they would complete would be easy or hard and were provided with a description of the procedure that followed. They were first given a practice task, in which the difficulty was the same as the subsequent 10 tasks, and then asked how confident they were that they would get the answer right on each of the following tasks on a scale from 0-1. Here, 1 is completely confident, and 0 is not confident at all. Intervals were set at 0.1 units. We presented participants with a number that flashed on the screen along with an arithmetic sign, either a +, -, x, or ÷. In each easy trial, the item flashed on the screen for 3 seconds. Numbers ranged from 1-10. After the item disappeared, the screen went blank for 2 seconds. After this brief period, a new item appeared with a new number and arithmetic sign. Participants had to keep a running tally of the arithmetic total of the presented numbers. When an = sign appeared, participants had to indicate their arithmetic total. For the hard trials participants completed the same task with less time between items (2 seconds). Numbers ranged between 1-100. Following the = sign, they had to indicate an arithmetic total.

Analysis

Those in the well-rested group were compared to those in the sleep-deprived group in terms of their scores on easy or hard memory tasks in relation to their perceived levels of confidence. We expected a statistically significant difference in calibration between the sleep-deprived and well-rested group on the hard task but not the easy task. We performed a 2X2 between subjects, factorial analysis of variance (ANOVA). Due to a violation of homogeneity of variance, we had to change our analytical method to a one-way ANOVA with four groups: sleep-deprived with easy tasks, sleep-deprived with hard tasks, well-rested with easy tasks, and well-rested with hard tasks. An alpha level of .05 was adopted. Statistical power analyses were based on Cohen's d and were calculated using G*Power algorithms.

Results

We tested the hypothesis that chronic sleep deprivation and task difficulty affect calibration during a working memory task. The homogeneity of variances assumption was tested with Levene's test of homogeneity of variances. The assumption was violated ($F(3,30) = 8.70$, $p < .01$). Therefore, we decided to conduct a one-way ANOVA with four conditions. These four conditions were: sleep-deprived and difficult tasks, sleep-deprived and easy tasks, well-rested and difficult tasks, and well-rested and easy tasks. The F-estimate that is robust to a violation of the assumption of homogeneity of variance (Brown-Forsythe) was used in reporting ANOVA results. The differences between conditions according to one-way ANOVA results were non-significant (*F* (3,30) = 1.39, *p* = .319). Sleep-deprived participants were no worse at calibrating their performance during easy (M = 0.17, SD = 0.19) or hard (M = 0.07, SD = 0.08) working memory tasks than well-rested participants were during easy (M = 0.10, SD = 0.22) or hard (M = 0.03, SD = 0.04) working memory tasks. These results fail to support our hypothesis that sleep-deprived participants would be less calibrated in their judgments than well-rested participants during a difficult task.

Discussion

In the present study, we aimed to explore whether chronic sleep deprivation affects one's metacognitive ability to make accurate confidence judgments about their success on a working memory task (calibration) and whether this effect depends on the task difficulty. Past research has shown that acute sleep deprivation has no effect on calibration scores in adults. However, not much research has been done to explore the effects of chronic sleep deprivation on calibration scores during a working memory task. Based on previous research that metacognitive judgments may be susceptible to long-term sleep deficits (Fraser et al., 2013) and task difficulty (Kvidera & Koutstall, 2008), we expected that sleep-deprived participants would have lower calibration scores during a difficult working memory task.

Contrary to expectations, statistical analysis revealed that neither sleep condition nor task difficulty influenced calibration scores. This may suggest that calibration judgments for working memory tasks are not as susceptible to sleep deprivation or task difficulty as other cognitive tasks. Expanding on Baranski's (2007) study, it may be the case that there is no difference between acute and chronic sleep-deprived individuals in their ability to monitor performance on cognitive tasks and that chronically sleep-deprived individuals are just as good at monitoring their working memory performance as well-rested individuals. If this is the case, and people are well-calibrated in their judgments, even after of chronic sleep deprivation, the motivations for destructive behaviors such as overnight cramming should be studied in more depth.

In addition to the theoretical explanations, there are some methodological considerations that can explain the non-significant results. Most importantly, our parameter of "less than 7 hours" for sleep deprivation may not have accurately distinguished between the sleep-deprived and well-rested. Some research suggests that some individuals may need less sleep than others and that, in some cases, 7 hours or less may be an optimal amount of sleep for some individuals (Shi et al., 2019; Spurgeon, 2002). Thus, some participants in our study who were categorized as “sleep deprived” may not have been deprived of sleep. Furthermore, recent research has demonstrated that rather than sleep duration, sleep consistency of the day/night cycle, also known as sleep regularity, can be a stronger predictor of certain health outcomes. (Windred et al., 2024).

Additionally, we had a very small sample size, so we had limited power to detect small or even medium effects, and the study was not a true experiment, so we could not truly control for confounding variables, such as differences in sleep quality or individual differences in optimal sleep ranges. We also used a self-report method, so participants may not have been accurate in indicating their sleep quantity, and therefore, this could have skewed the results. For example, one may think that they are not sleep-deprived when they are, while the opposite could also be true. Thus, future research would benefit from using a larger sample size and ensuring the accuracy of sleep quantity and quality by conducting a similar study using medical equipment to measure sleep, in which brain waves are monitored and sleep stages are analyzed. In doing this, we could draw more reliable conclusions on how chronic sleep loss affects metacognitive judgments. Our study may have important implications for encouraging healthy sleeping habits for college students, as well as for those in professions in which cognitive tasks are routine.

References

Ackerman, P. L., & Wolman, S. D. (2007). Determinants and validity of self-estimates of abilities and self-concept measures. *Journal of Experimental Psychology: Applied*, 13, 57–78. https://doi.org/10.1037/1076-898X.13.2.57

Angus, R. G., & Heslegrave, R. J. (1985). Effects of sleep loss on sustained cognitive performance during a command and control simulation. *Behavioral Research Methods Instruments & Computers*, 17, 55–67. https://doi-org/10.3758/BF03200897

Babkoff, H., Caspy, T., & Mikulincer, M. (1991). Subjective sleepiness ratings: The effects of sleep deprivation, circadian rhythmicity and cognitive performance. *Sleep*, 14, 534–539. https://doi-org/10.1093/sleep/14.6.534

Baranski, J. V. (2007). Fatigue, sleep loss, and confidence in judgment. *Journal of Experimental Psychology: Applied*, 13(4), 182–196. https://doi.org/10.1037/1076-898x.13.4.182

Baranski, J. V., Gil, V., McLellan, T., Moroz, D., Buguet, A., & Radomski, M. (2002). Effects of modafinil on cognitive performance during 40 hours of sleep deprivation in a warm environment. *Military Psychology*, 14, 23–48. https://doi-org/10.1207/S15327876MP1401_02

Baranski, J. V., & Pigeau, R. (1997). Self-monitoring cognitive performance during sleep deprivation: Effects of modafinil, d-amphetamine and placebo. *Journal of Sleep Research*, 6, 84–91. https://doi-org/10.1111/j.1365-2869.1997.00032.x

Blagrove, M., & Akehurst, L. (2000). Effects of sleep loss on confidence–accuracy relationships for reasoning and eyewitness memory. *Journal of Experimental Psychology: Applied*, 6, 59–73. https://doi.org/10.1037/1076-898X.6.1.59

Cabral, L. G., Queiroz, T. N., Pol-Fachin, L., & Santos, A. R. (2022). Digital technology and its impacts on the sleep quality and academic performance during the pandemic. *Arquivos de Neuro-Psiquiatria*, 80(10), 1052–1056. https://doi.org/10.1055/s-0042-1755395

Chee, M. W. L., & Choo, W. C. (2004). Functional imaging of working memory after 24 hours of total sleep deprivation. *The Journal of Neuroscience,* 24, 4560–4567. https://doi.org/10.1523/JNEUROSCI.0007-04.2004

Chen, W.-L., & Chen, J.-H. (2019). Consequences of inadequate sleep during the college years: Sleep deprivation, grade point average, and college graduation. *Preventive Medicine,* 124, 23–28. https://doi.org/10.1016/j.ypmed.2019.04.017

Coren, S. (1997). Sleep thieves. New York: Free Press.

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: Wiley.

Dorrian, J., Lamond, N., & Dawson, D. (2000). The ability to self-monitor performance when fatigued. *Journal of Sleep Research*, 9, 137–144. https://doi.org/10.1046/j.1365-2869.2000.00195.x

Drummond, S., Brown, G. (2001). The Effects of Total Sleep Deprivation on Cerebral Responses to Cognitive Performance. *Neuropsychopharmacol*. 25 (Suppl 1), S68–S73. https://doi.org/10.1016/S0893-133X(01)00325-6

Drummond, S. P. A., Brown, G. G., Gillin, J. C., Stricker, J. L., Wong, E. C., & Buxton, R. B. (2000). Altered brain response to verbal learning following sleep deprivation. *Nature*, *403*(6770), 655–657. https://doi.org/10.1038/35001068

Drummond, S. P. A., Brown, G. G., Stricker, J. L., Buxton, R. B., Wong, E. C., Gillin, J. C. (1999). Sleep deprivation-induced reduction in cortical functional response to serial subtraction. *NeuroReport*, *10*(18), 3745-3748. https://doi.org/10.1097/00001756-199912160-00004

Durmer, J. S., & Dinges, D. F. (2005). Neurocognitive consequences of sleep deprivation. *Seminars in Neurology,* 25, 117–129. https://doi.org/10.1055/s-2005-867080

Fernandez-Duque, D., Baird, J. A., & Posner, M. I. (2000). Executive attention and metacognitive regulation. *Consciousness and Cognition*, 9, 288–307.

Fraser, M., Conduit, R., & Phillips, J. G. (2013). Effects of sleep deprivation on decisional support utilisation. *Ergonomics*, *56*(2), 235–245. https://doi.org/10.1080/00140139.2012.760754

Harrison, Y., & Horne, J. A. (1998). Sleep deprivation impairs short and novel language tasks having a prefrontal focus. *Journal of Sleep Research,* 7, 95–100. https://doi.org/10.1046/j.1365-2869.1998.00104.x

Harrison, Y., & Horne, J. A. (1999). One night of sleep loss impairs innovative thinking and flexible decision making. *Organizational Behavior and Human Decision Making,* 78, 128–145. https://doi.org/10.1006/obhd.1999.2827

Harrison, Y., & Horne, J. A. (2000). The impact of sleep deprivation on decision making: A review. *Journal of Experimental Psychology: Applied*, 6, 236–249. https://doi.org/10.1037/1076-898X.6.3.236

Harrison, Y., Horne, J. A., & Rothwell, A. (2000). Prefrontal neuropsychological effects of sleep deprivation in young adults—A model for healthy aging? *Sleep*, 23, 1–7. https://doi.org/10.1093/sleep/23.8.1f

Kvidera, S., & Koutstaal, W. (2008). Confidence and decision type under matched stimulus conditions: Overconfidence in perceptual but not conceptual decisions. *Journal of Behavioral Decision Making*, *21*(3), 253–281. https://doi.org/10.1002/bdm.587

Krueger, G. P. (1989). Sustained work, fatigue, sleep loss and performance: A review of the issues. *Work & Stress,* 3, 129–141. https://doi-org/10.1080/02678378908256939

Liberman V. (2004). Local and global judgments of confidence. *Journal of experimental psychology. Learning, memory, and cognition*, *30*(3), 729–732. https://doi.org/10.1037/0278-7393.30.3.729

Mazzoni, G., & Nelson, T. (1998). Metacognition and cognitive neuropsychology: Monitoring and control processes. Mahwah, NJ: Erlbaum.

Philip, P., Sagaspe, P., Prague, M., Tassi, P., Capelli, A., Bioulac, B., Commenges, D., & Taillard, J. (2012). Acute versus chronic partial sleep deprivation in middle-aged people: Differential effect on performance and sleepiness. *Sleep*, 35(7), 997–1002. https://doi.org/10.5665/sleep.1968

Shi, G., Xing, L., Wu, D., Bhattacharyya, B. J., Jones, C. R., McMahon, T., Chong, S. Y. C., Chen, J. A., Coppola, G., Geschwind, D., Krystal, A., Ptáček, L. J., & Fu, Y. H. (2019). A rare mutation of β1-adrenergic receptor affects sleep/wake behaviors. *Neuron*, *103*(6), 1044–1055. https://doi.org/10.1016/j.neuron.2019.07.026

Spurgeon D. (2002). People who sleep for seven hours a night live longest. *BMJ : British Medical Journal*, *324*(7335), 446.

Wilkinson, R. T. (1965). Sleep deprivation. In O.Edholm & A.Bacharach (Eds.), *The physiology of human survival* (pp. 399–430). New York: Academic Press.

Wilkinson, R. T. (1969). Sleep deprivation: Performance tests for partial and selected sleep deprivation. In L. E.Abt & B. F.Riess (Eds.), *Progress in clinical psychology* (pp. 28–43). New York: Grune & Stratton.

Windred, D. P., Burns, A. C., Lane, J. M., Saxena, R., Rutter, M. K., Cain, S. W., & Phillips, A. J. K. (2024). Sleep regularity is a stronger predictor of mortality risk than sleep duration: A prospective cohort study. *Sleep: Journal of Sleep and Sleep Disorders Research*, *47*(1), 1–11. https://doi-org.ezproxy.kpu.ca:2443/10.1093/sleep/zsad253

Zhang, Y., Tolmie, A., & Gordon, R. (2022). The relationship between working memory and arithmetic in primary school children: A meta-analysis. *Brain Sciences*, *13*(1), 22. https://doi.org/10.3390/brainsci13010022