Journal of the
Bahrain Medical Society

Almusalam et al., J Bahrain Med Soc. 2024;36(4):21-31

ORIGINAL ARTICLE

The Effect of Sleep Deprivation on Junior Physicians' Cognitive Performance and Irritability in the Kingdom of Bahrain

Abdulla Almusalam[1]*, Israa Sinan[2]

[1]MsC. Head of Scientific Research & Development, King Hamad University Hospital.

[2]BsC. Scientific Researcher, King Hamad University Hospital.

***Corresponding author:**

Abdulla Almusalam. Head of Scientific Research & Development, King Hamad University Hospital, King Hamad University Hospital. Building 2435, Road 2835, Block 228, P.O Box 24343, Busaiteen, Kingdom of Bahrain; Tel. No.: +973-39673888 ; E-Mail: Abdulla.k.almusalam@gmail.com

Received date: October 09, 2024; **Accepted date:** November 12, 2024; **Published date:** December 31, 2024

Abstract

Background: Sleep is a crucial part of any stage of life to provide a resting period that is essential for decision-making matters, and mood, as well as to help the body reduce blood pressure and cardiovascular complications. Dealing with sleep deprivation is not uncommon for junior physicians working in healthcare, causing a decline in cognition which affects decision-making, and mood changes that cause irritability.

Aims: This study aims to measure the changes in visual working memory and mood within the junior physician population that faces sleep deprivation due to on-call shifts.

Methods: Following the recruitment of participants, they were asked to complete the Pittsburgh Sleep Quality Index (PSQI) to assess sleep quality and disturbances over 1 month. Following that, the participants were then requested to complete a Brief Mood Introspection Scale (BMIS) to measure their mood, as well as a visual working memory assessment (cognitive task) to assess cognitive functions. The BMIS and cognitive tasks were completed before and after their on-call shifts. Furthermore, the participants were requested to complete the BMIS and cognitive task on "normal shifts", which was used as a control group.

Results: It has been observed that there are no statistically significant correlations between the cognition score and any of the BMIS sub-scales in the pre-call visit. However, within the post-call visit, positively associated moods in the BMIS sub-scales such as pleasantness ($r = 0.414$, $p = 0.035$) and overall positivity ($r = 0.486$, $p = 0.012$) had a statistically significant effect on cognitive scores. For the normal shift visit, all of the positively associated BMIS sub-scales had a statistically significant effect on cognitive scores: pleasantness ($r= 0.640$, $p = 0.014$), arousal ($r = 0.570$, $p = 0.033$) and overall positivity ($r = 0.660$, $p = 0.011$).

Conclusion: Sleep deprivation affects junior physicians immensely causing a decrease in positive mood and cognitive decline. Upon this reflection, medical institutions need to actively pay attention to the mental health and well-being of junior physicians to ensure that patient care is not halted or compromised.

Keywords: Sleep Deprivation, Visual Working Memory, Cognitive Impairment, Mood

Introduction

According to the National Sleep Foundation, the recommended time for sleeping in adults is 7-9 hours, accounting for one-third of an individual's day. This state of perceptual disengagement from the environment serves as a resting period that is essential for cognitive, mood, and physiologic functions, as well as emotion regulation.[1,3] Individuals who habitually deviate from the recommended guidelines may exhibit signs or symptoms of serious health complications, whether they are physical, mental, or emotional. Physical complications include increased cortisol levels, decreased glucose tolerance, and increased sympathetic tone[4], which can lead to increased blood pressure and cardiovascular complications. [5-6] Continuous deprivation of sleep can also lead to non-physical detriments. In a study conducted at the University of Pennsylvania, 16 healthy adults had their sleep restricted to 4.98 hours per night for seven days. The study showed that there is a clear effect of sleep deprivation on neurobehavioral markers such as alertness, mood disturbances, and stress.[7] Moreover, sleep deprivation has been shown to induce mental fatigue whilst performing important tasks such as operating vehicles.[8] A lack of sleep can cause a multitude of problems that can restrict an individual's ability to perform daily tasks optimally, whether it is about work, social settings or even enjoying hobbies.

Physicians are a unique demographic that is prone to continuous sleep disturbances due to their inconsistent work hours and on-call duties, alongside the responsibilities they hold. As a result, reduced sleep can deteriorate their mood, attitude, perceived efficiency, and information processing; which can lead to reduced cognitive functions.[9,10] These reduced cognitive functions can severely affect a physician's ability to provide the best level of care to their patients, whether it is through consultations and diagnosis, prescribing medication, or performing surgical procedures.[11]

Working memory is a multi-component model that encompasses three subcomponents:[13]

1) Phonological loop [verbal working memory], 2) Visuospatial sketchpad [visual-spatial working memory], 3) Central executive [allows for directing attention, maintaining task goals, decision making, and memory retrieval].[13,14] Multiple variables play a debilitating role in the capacity of working memory, or how many items an individual can hold in their mind and later be used in the execution of cognitive tasks, such as negative emotions, increased stress and anxiety, mindfulness, and sleep.[15]

In this study, we aim to address the concerns regarding sleep deprivation and mood in junior physicians. We hypothesize that sleep deprivation will have detrimental effects on cognition and mood. Physicians who are sleep-deprived are more likely to show a decline in both cognitive abilities and mental health. In that same manner, we expect our participants to have worsening scores on the cognitive assessment after completing their on-call shift.

Methods

Ethical Approval

The study was ethically approved by the Institutional Review Board at King Hamad University Hospital (IRB#22-561). Following approval, a list of junior physicians who were eligible for the study was retrieved from the hospital administration.

Study Design

This study followed a prospective quasi-experimental design at King Hamad University Hospital, Bahrain. The participants' inclusion criteria were that they have at least six months' experience working in the hospital. The participants were all physicians with on-call duties, required to stay on hospital premises after their normal duty hours with a minimum of 20 hours. Participants were excluded if they were doing on-call shifts outside the hospital premises such as pathologists, or if they worked in specialties that have shift-based work hours such as Emergency Medicine, Intensive Care Unit (ICU), or Pediatric Intensive Care Unit (PICU). Additionally, if the participants were diagnosed with psychological disorders that may affect cognition or sleep, they were excluded. Following this criterion, and the physicians' availability, 26 physicians enrolled in the study.

Patient Recruitment

Participants were initially emailed about the study and then contacted through the phone about their willingness to participate. Upon verbal agreement to participate, they were asked about their next on-call shift for which they can accommodate 10 minutes of their time the morning of the on-call shift and the afternoon of the next day after completing their shift. Then, the participants were sent an electronic Informed Consent and a survey that included: 1) Demographics, 2) a Motor Vehicle Survey, and 3) the Pittsburgh Sleep Quality Index (PSQI). 4) Brief Mood Introspection Scale (BMIS) to complete. The survey was electronically done on Microsoft Forms and a participant number was assigned upon completion. Participants were not permitted to complete the survey if they did not consent to participate in the study.

Data Variables

1) Demographical Variables

Demographic variables were recorded through the online survey that required participants to complete it using their institutional accounts. This feature helped us track the participants between the first and second visits. The demographic variables are age and gender, smoking habits, marital status if they have any children, and how many. Work-related variables that were collected are the specialties they work in, the number of years of experience they had accumulated, the average number of on-call shifts in a month, and their normal working hours. Lifestyle variables such as the number of coffee cups they drink a day and the average number of hours they sleep on a normal day were also accounted for. In addition, to confirm that participants fit the inclusion criteria, they were asked if they were diagnosed with any sleeping disorders. This survey was only completed once per participant.

2) Motor Vehicle Survey

A motor vehicle survey was included in the initial survey to see if participants recorded disturbances in driving between their regular shifts and on-call shifts through any major or minor accidents (Appendix A). This survey was created by the investigators using a 5-point Likert Scale response model [Very unlikely, Unlikely, Neutral, Likely, Very Likely]. The participants were asked after a normal shift what the likelihood is of being in a minor or major accident. Similarly, they were asked after an on-call shift what the likelihood is of them being in a minor or major accident. This survey was only completed once per participant. As per the observational traffic and accident system in the Kingdom of Bahrain: 1) Minor accidents are defined as driving at high speeds over a speed bump and/or frequently driving over Bott's dots. 2) Major accidents are defined as direct contact or a near miss with another vehicle or object and/or a collision that results in damage to their vehicles. Higher scores on this survey indicate a higher likelihood of being in the respective accident type. This survey was only completed once per participant.

3) Pittsburgh Sleep Quality Index (PSQI)

This index was used to assess sleep quality and disturbances over 1 month. The scores of the 19 items generate seven different "component" scores: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. Each component can be scored from 0 being no difficulty to 3 being severe difficulty. The results of this questionnaire allowed the division of the participants into either good sleepers or bad sleepers.[16] This survey was only completed once per participant.

4) Brief Mood Introspection Scale (BMIS)

The survey consists of 16 emotions used to measure the current mood of the participants. The scoring of this scale was followed as per the literature (BMIS-technical) and reverse-coding was done as per the instructions.[17] There were four sub-scales: Pleasant-Unpleasant, Arousal-Calm, Positive-Tired, and Negative-Relaxed. Each sub-scale is calculated by either subtracting negatively associated emotions from positively associated emotions (ex: Pleasant-Unpleasant) or subtracting positively associated emotions from negatively associated emotions (ex: Negative-Relaxed). Participants were asked to fill this survey out before starting the cognitive assessment in both pre-call and post-call sessions.

5) Cognitive Assessments

Upon their arrival on the morning of the on-call shift or after their on-call shift the next day, the participants were directed to a quiet room that was clear of distractions. Once they had completed the BMIS survey, participants were given a demo of the GoCognitive Working Memory Test software which consisted of 20 trials [Appendix B]. Each trial consisted of a digit sequence that appeared every 2 seconds, which participants were instructed to remember serially. The test started with five digits at a two-second speed interval with no sound. The test records participants' performance and provides a final score, which was used as a measure of individual working memory capacity. Higher scores represent greater working memory capacity. This survey was filled out once per visit.

6) Sleeping Hours

Doctors were asked upon their arrival after the on-call shifts about the number of hours they had slept during this shift. All doctors came at least 20 hours after their initial pre-on-call session.

7) Follow-up Visit

Participants who attended both visits of the study were asked for a follow-up to repeat the BMIS survey and cognitive task during a normal shift that did not consist of any on-call responsibilities. This follow-up visit was used as a control measure for their cognitive performance and mood.

Data Analysis

Data analysis was carried out after the data collection phase in which SPSS v 25.0 was used for testing relationships between sleep deprivation, cognition, and mood.

Results

Participant Characteristics

This study was conducted on 26 junior physicians, all of whom were able to complete the relevant surveys and cognitive tasks for their pre-call and post-call conditions. However, 14 of those 26 participants also complied with the follow-up in which they completed the BMIS and cognitive assessment during their normal shift. Those who did not comply with the follow-up were not excluded from the study as their data remains valuable for the investigation of sleep deprivation and mood on cognitive function. Table 1 summarizes the demographic and occupational characteristics. The majority of residents were male (61.5%), single (88.5%) who had been working for more than 2 years (46.2%). The average physician is assigned 6 on-call shifts a month, and the results of the PSQI indicate that 96.2% of them are bad sleepers.

Table 1: Population Demographics (n=26)

Variable	Mean ± SD / n (%)
Age	27.19 ± 1.72
Gender	
Male	16 (61.5%)
Female	10 (38.5%)
Marital Status	
Single	23 (88.5%)
Married	3 (11.5%)
Specialty	
Anesthesia	1 (3.8%)
General Surgery	4 (15.4%)
Internal Medicine	7 (26.9%)
OB-GYN	2 (7.7%)
Orthopedic	5 (19.2%)
Pediatrics	2 (7.7%)
Radiology	3 (11.5%)
Urology	2 (7.7%)
Smoking	
Yes	6 (23.1%)
No	20 (76.9%)
Do you have children?	
Yes	1 (3.8%)
No	25 (96.2%)
How many years have you been working?	3 (IQR: 2-3)
1	7 (26.9%)
2	7 (26.9%)

Variable	Mean ± SD / n (%)
Do you have children?	
>2	12 (46.2%)
How many on-calls are you assigned per month?	6 (IQR: 6-7)
How many cups of coffee do you drink a day?	2 (IQR: 1-2.25)
PSQI	(8.46 ± 2.25) (IQR: 7-10)
Good sleepers	1 (3.8%)
Bad sleepers	25 (96.2%)

Table 2 shows the relationships between the junior physicians' confidence in operating motor vehicles from their place of work to home. There is a major increase in averages between the normal work shift and on-call shift for both minor accidents (M: 1.96 to M:3.54) and major accidents (M: 1.54 to M: 3.04).

Table 2: Motor Vehicle Accident Survey

Variable	Mean ± SD	Median	P value
Minor accident			
Normal shift	1.96 ± 1.08	2 (IQR: 1-3)	0.46
On-call shift	3.54 ± 1.14	4 (IQR:3-4.25)	0.23
Major accident			
Normal shift	1.54 ± 0.91	1 (IQR:1-2)	0.69
On-call shift	3.04 ± 1.28	3 (IQR: 2-4)	0.15

Table 3 highlights the severity of sleep deprivation among junior physicians within the past month of participating in this study. This table uses the mean scores of each subscale within the PSQI as well as the sum of all seven components to generate a Global PSQI Score. The majority of junior physicians are considered "Bad Sleepers" as their Global PSQI Score is greater than 5 (M: 8.46, SD: 2.25). The most prevalent sub-scale qualities that indicate disturbed sleep among this population are Sleep Quality (M: 1.46, SD: 0.58), Sleep Latency (M: 1.46, SD: 0.81), Sleep Duration (M: 2.00, SD: 0.57) and Daytime Dysfunction (M: 1.65, SD: 0.80).

Table 3: Self-reported sleep quality measures (PSQI)

Sleep Quality assessment	Mean± Standard Deviation
Pittsburg Sleep Quality Index (PSQI) total score	8.46 ± 2.25
Pittsburg Sleep Quality Index (PSQI) subscales	
Sleep Quality	1.46 ± 0.58
Sleep latency	1.46 ± 0.81
Sleep duration	2.00 ± 0.57
Habitual sleep efficiency	0.58 ± 0.81
Sleep disturbance	1.12 ± 0.52
Use of sleep medications	0.19 ± 0.49
Daytime dysfunction	1.65 ± 0.80

Data are displayed as mean and standard deviation.

PSQI total scale ranges from 0 to 21; sub-score ranges from 0 to 3

Table 4 shows a statistically significant decrease in positively associated mood subscales and a statistically significant increase in negatively associated mood subscales between the pre-call and post-call visits. There was a decrease in pleasantness (M: 46.23 to M: 36.62), arousal (M: 30.65 to M: 28.58), overall positivity (M: 20.42 to M: 14.81), and an increase in negativity (M: 13.38 to M: 15.69).

Table 4: Difference in BMIS sub-scales between pre-call and post-call junior physicians

Sleep Quality assessment	Pre-call	Post-call	Difference	P value
Pleasant-Unpleasant	46.23 ± 5.83	36.62 ± 8.28	-9.61	**0.000**
Arousal-Calm	30.65 ± 3.01	28.58 ± 3.05	-2.07	**0.017**
Positive-Tired	20.42 ± 2.70	14.81 ± 4.00	-5.61	**0.000**
Negative-Relaxed	13.38 ± 2.62	15.69 ± 3.38	+2.31	**0.008**

Table 5 and Figure 1 show a statistically significant decrease in positively associated mood subscales and a statistically significant increase in negatively associated mood subscales between the normal working shift and post-call visits. There was a decrease in pleasantness (M: 45.79 to M: 36.62), overall positivity (M: 18.86 to M: 14.81), and an increase in negativity (M: 12.57 to M: 15.69).

Table 6 showcases the correlations between cognition score and mood in all three visits (pre-call, post-call, and normal shift) [Appendix C-E). It has been observed that there are no statistically significant correlations between the cognition score and any of the BMIS sub-scales in the pre-call visit. However, within the post-call visit, pleasantness (r = 0.414, p = 0.035) and overall positivity (r = 0.486, p = 0.012) had a statistically significant effect on cognitive scores. For the normal shift visit, all of the positively associated BMIS sub-scales had a statistically significant effect on cognitive scores: pleasantness (r= 0.640, p = 0.014), arousal (r = 0.570, p = 0.033) and overall positivity (r = 0.660, p = 0.011).

Table 7 shows the correlation between the number of hours slept throughout the on-call shift and cognition scores. However, it has been noted that the average cognition score decreased by 0.84 (M: 6.82 to 5.98) if the physician slept for zero hours. Moreover, if the physician has slept for at least 1 hour, there is a less impactful decrease in cognitive score.

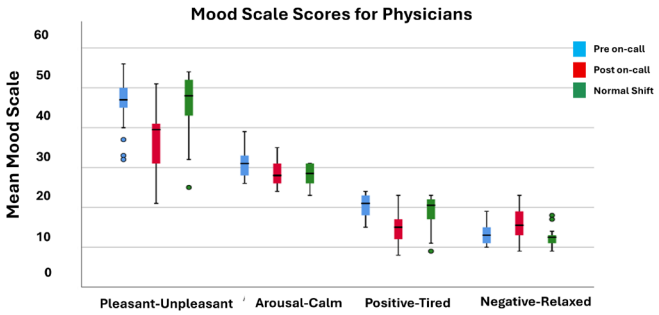


Figure 1: Box and Whisker plot for Mood Scores Between Shifts

Table 5: Difference in BMIS sub-scales between normal working shift and post-call junior physicians

Sleep Quality assessment	Normal Shift	Post-call	Difference	P value
Pleasant-Unpleasant	45.79 ± 8.37	36.62 ± 8.28	-9.17	**0.002**
Arousal-Calm	28.36 ± 2.56	28.58 ± 3.05	+0.22	**0.820**
Positive-Tired	18.86 ± 4.19	14.81 ± 4.00	-4.05	**0.005**
Negative-Relaxed	12.57 ± 2.59	15.69 ± 3.38	+3.12	**0.005**

Table 6: Paired Samples Correlations Between Cognition Score and Mood

Sleep Quality assessment	Pre-on-Call	Post-on-Call	Normal Shift
Pleasant-unpleasant	r = 0.011 (p = 0.956)	r = 0.414 (p = 0.035)	r = 0.640 (p = 0.014)
Arousal-calm	r = -0.135 (p = 0.511)	r = 0.225 (p = 0.268)	r = 0.570 (p = 0.033)
Positive-tired	r = -0.085 (p = 0.679)	r = 0.486 (p = 0.012)	r = 0.660 (p = 0.011)
Negative-relaxed	r = -0.032 (p = 0.876)	r = -0.182 (p = 0.372)	r = -0.41 (p = 0.150)

Table 7: Cognition scores and hours slept during on-call shift

Hours of Sleep	Pre-on-call	Post-on-call	Difference	P value
0	6.82 ±1.73	5.98 ± 0.37	-0.84	0.243
1	6.98 ± 0.70	6.82 ± 1.34	-0.16	0.663
2+	6.47 ± 0.87	6.35 ± 1.13	-0.12	0.637

Discussion

This study aims to measure the relationship between overall sleep quality and mood about cognition functions. It utilizes a visual working memory assessment that junior physicians undertook before and after their on-call shifts compared to their normal shifts. Further, the study aims to provide information on the significance of sleep among junior physicians as they work longer hours ranging from 24 to 36 hours, and must remain alert for optimal patient care.[18,19]

Sleep deprivation, acute or chronic, impairs attention and working memory, as well as functions such as decision-making and attention.[20] Our study indicates that 96.1% (n=25) of our population struggled with bad sleep habits through the PSQI scale. The average score was 8.46 and low scores in the sub-categories were: Sleep Quality [$\bar{x}$:1.46], Sleep Latency [$\bar{x}$:1.46], Sleep Duration [$\bar{x}$:2.00], and Daytime Dysfunction [$\bar{x}$:1.65]. These unhealthy sleeping patterns typically exacerbate mood disturbances.[21-23] Similarly, our results show a statistically significant decrease in pleasantness, arousal, and overall positive emotions following on-call shifts ($p = 0.000$, $p=0.017$, and $p=0.000$ respectively), while having a statistically significant increase in negatively associated emotions ($p= 0.008$).

Multiple sleep studies have concluded that working memory is sensitive to sleep deprivation. A study by Peng et al. (2020) has explored the effects of 36 hours of total sleep deprivation (TSD) on working memory through event-related potential (ERP).[24] They found that the amplitude of N2-P3 components related to working memory was decreased for the sleep-deprived group, indicating that TSD can impair working memory capacity. Other studies have also concluded that sleep deprivation is detrimental to working memory as it inhibits general attention and mnemonic abilities, as well as negatively influencing neural activation in frontal and parietal cortices, which are areas that are critical for working memory.[25]

While other studies measured both the accuracy and speed of sleep-deprived participants and noticed a cognitive decline, the current study only measured accuracy in recalling a sequence of numbers that were shown for a short period.[26-27] The current study showed a decline in visual working memory scores following an on-call shift. Similarly, these results have been displayed in literature such as in a prospective study involving surgical residents who had less than 3 hours of sleep, which showed that sleep-deprived surgeons make almost twice as many errors during a simulated laparoscopy [virtual reality], which indicates that motor functions are significantly affected by a lack of sleep.[28] This influence also carries over to physicians with less experience such as those who have just begun their careers. For example, sleep-deprived interns have been shown to make a greater number of medical errors when compared to a control group, as they were significantly less able to recognize arrhythmias on an electrocardiogram (ECG).[29] This study also found that interns felt increased sadness and decreased vigor, egotism, and social affection.

Furthermore, continuous lack of sleep not only affects working memory but also mood. Evident changes in mood as a result of sleep deprivation include anxiety, depression, and mood swings, with the most notable being anger and irritability.[21,30] A study done on junior physicians in Saudi Arabia explored mood alongside sleep deprivation in junior physicians.[31] The results showed that physicians had worsening mood post-call among their population. In a similar study in Singapore, they found that 89.5% of participants experienced adversely affected mood after an on-call shift.[32] Ultimately, these results indicate that physicians' ability to concentrate, make rapid judgments, prompt and correct decision-making, and have fine motor skills are decreased after on-call shifts. In parallel, we found that higher scores of pleasantness, arousal, and overall positive emotions in the BMIS have been positively correlated with higher cognitive functions; namely, pleasantness and overall positive emotions are statistically significant ($p=0.035$ and 0.012 respectively) whereas higher scores in negatively associated subscale were correlated with lower scores. Additionally, a study measuring attention and cognitive load through participants' responsiveness to stimuli in a computer task found that ruminative thoughts impaired cognitive functions.[33]

Limitation

Multiple junior physicians were unable to comply with the follow-up (control group) due to conflicting study schedules, rotations, or other important responsibilities, indicating a complex schedule for their lifestyle which plays a role in sleep deprivation. Furthermore, all of the study participants were recruited from only one hospital, and having different settings would not only increase the sample size but also allow the data to be more generalized for the physician population within Bahrain.

Conclusion

Sleep deprivation has been shown to reduce mood and cognitive ability, which can contribute to a person's ability to be productive and efficient in their work. This is especially true regarding physicians with long working hours and on-call duties, who are more susceptible to fatigue and cognitive decline, affecting their ability to deliver the best standard of care possible. This study was conducted to promote health institutions to monitor the mental health and well-being of junior physicians to reduce burnout and the possibility of lower-quality care as a result of sleep deprivation.

References

1. Hirshkowitz M, Whiton K, Albert SM, et al.: National Sleep Foundation's updated sleep duration recommendations. Sleep health. 20151, 1:233-43. 10.1016/j.sleh.2015.10.004.
2. Carskadon MA, Dement WC: Normal human sleep: an overview. Principles and practice of sleep medicine. 20051, 4:13-23.
3. Hardin, Kimberly A. (2009: Sleep in the ICU. Chest. 136:284-294. 10.1378/chest.08-1546.
4. Spiegel K, Leproult R, Van Cauter E: Impact of sleep debt on metabolic and endocrine function.. 1999, 23:1435-9. 10.1016/S0140-6736(99)01376-8.
5. Tochikubo O, Ikeda A, Miyajima E, Ishii M: Effects of insufficient sleep on blood pressure monitored by a new multibiomedical recorder. Hypertension. 1996, 27:1318-24. 10.1161/01.hyp.27.6.1318.
6. Wolk R, Gami AS, Garcia-Touchard A, Somers VK: Sleep and cardiovascular disease. Current problems in cardiology. 20051, 30:625-62. 10.1016/j.cpcardiol.2005.07.002.
7. Dinges DF, Pack F, Williams K, et al.: Cumulative sleepiness, mood disturbance, and psychomotor vigilance performance decrements during a week of sleep restricted to 4-5 hours per night. Sleep. 19971, 20:267-77.
8. Ahn S, Nguyen T, Jang H, Kim JG, Jun SC: Exploring neuro-physiological correlates of drivers' mental fatigue caused by sleep deprivation using simultaneous EEG, ECG, and fNIRS data. Frontiers in human neuroscience. 2016, 13:219. 10.3389/fnhum.2016.00219.
9. Jacques CH, Lynch JC, Samkoff JS: The effects of sleep loss on cognitive performance of resident physicians. Journal of Family Practice. 19901, 30:223-30.
10. Leighton K, Livingston M: Fatigue in doctors. The Lancet. 1983 Jun 4. 321:1280. 10.1016/s0140-6736(83)92732-0.
11. Olson EJ, Drage LA, Auger RR: Sleep deprivation, physician performance, and patient safety. Chest. 2009, 1:1389-96. 10.1378/chest.08-1952.
12. Chai WJ, Abd Hamid AI, Abdullah JM: Working memory from the psychological and neurosciences perspectives: a review. Frontiers in psychology. 2018, 27:401. 10.3389/fpsyg.2018.00401.
13. McCabe DP, Roediger III HL, McDaniel MA, Balota DA, Hambrick DZ: The relationship between working memory capacity and executive functioning: evidence for a common executive attention construct. Neuropsychology. 2010, 24:222. 10.1037/a0017619.
14. Vitiello MV, Schwartz RS, Moe KE, Mazzoni G, Merriam GR: Treating age-related changes in somatotrophic hormones, sleep, and cognition. Dialogues in Clinical Neuroscience. 2001, 30:229-36. 10.31887/DCNS.2001.3.3/mvvitiello.

15. Blasiman RN, Was CA: Why is working memory performance unstable? A review of 21 factors. Europe's journal of psychology. 2018, 14:188. 10.5964/ejop.v14i1.1472.

16. Zhong QY, Gelaye B, Sánchez SE, Williams MA: Psychometric properties of the Pittsburgh Sleep Quality Index (PSQI) in a cohort of Peruvian pregnant women. Journal of Clinical Sleep Medicine. 2015, 15:869-77. 10.5664/jcsm.4936.

17. Mayer JD, Cavallaro R: Brief mood introspection scale (BMIS): Technical and scoring manual.

18. Gaba DM, Howard SK: Fatigue among clinicians and the safety of patients. New England Journal of Medicine. 2002, 17:1249-55. 10.1056/NEJMsa020846.

19. Mansukhani MP, Kolla BP, Surani S, Varon J, Ramar K: Sleep deprivation in resident physicians, work hour limitations, and related outcomes: a systematic review of the literature. Postgraduate medicine. 2012, 1:241-9. 10.3810/pgm.2012.07.2583.

20. Alhola P, Polo-Kantola P: Sleep deprivation: Impact on cognitive performance. Neuro-psychiatric disease and treatment. 2007, 3: 553-67.

21. Saghir Z, Syeda JN, Muhammad AS, Abdalla TH: The amygdala, sleep debt, sleep deprivation, and the emotion of anger: a possible connection?. Cureus. 201810, 10.7759/cureus.2912.

22. Short MA, Louca M: Sleep deprivation leads to mood deficits in healthy adolescents. Sleep medicine. 2015, 16:987-93. 10.1016/j.sleep.2015.03.007.

23. Paterson JL, Dorrian J, Ferguson SA, Jay SM, Dawson D: What happens to mood, performance and sleep in a laboratory study with no sleep deprivation?. Sleep and biological rhythms. 2013, 11:200-9. 10.1111/sbr.12023.

24. Peng Z, Dai C, Ba Y, Zhang L, Shao Y, Tian J: Effect of sleep deprivation on the working memory-related N2-P3 components of the event-related potential waveform. Frontiers in neuroscience. 202019, 14:469. 10.3389/fnins.2020.00469.

25. Frenda SJ, Fenn KM: Sleep less, think worse: the effect of sleep deprivation on working memory. Journal of Applied Research in Memory and Cognition. 20161, 5:463-9. 10.1016/j.jarmac.2016.10.001.

26. Ratcliff R, Van Dongen HP: Sleep deprivation affects multiple distinct cognitive processes. Psychonomic bulletin & review. 2009, 16: 742-51.

27. Bougard C, Moussay S, Espié S, Davenne D: The effects of sleep deprivation and time of day on cognitive performance. Biological Rhythm Research. 2016, 3:401-15. 10.1080/09291016.2015.1129696.

28. Grantcharov TP, Bardram L, Peter FJ, Rosenberg J: Laparoscopic performance after one night on call in a surgical department: prospective study. . Bmj. 2001, 24:1222-3. 10.1136/bmj.323.7323.1222.

29. Friedman RC, Bigger JT, Kornfeld DS: The intern and sleep loss. . The New England Journal of Medicine. 2001, 10.1056/NEJM197107222850405.

30. Bauducco SV, Flink IK, Jansson-Fröjmark M, Linton SJ: Sleep duration and patterns in adolescents: correlates and the role of daily stressors. Sleep health. 2013, 8:211-8. 10.1016/j.sleh.2016.05.006.

31. Wali SO, Qutah K, Abushanab L, Abushanab J, Krayem A: Effect of on-call-related sleep deprivation on physicians' mood and alertness. Annals of thoracic medicine. 2013, 8:22-7. 10.4103/1817-1737.105715.

32. Puvanendran K, Venkatramani J, Jain A, Farid M: Sleep deprivation in junior doctors—house officers in Singapore. Industrial Health. 2005, 43:129-32. 10.2486/indhealth.43.129.

33. Brinker JK, Campisi M, Gibbs L, Izzard R: Rumination, mood and cognitive performance. Psychology. 2013, 28:224. 10.4236/psych.2013.43A034.

Appendix A: Motor Vehicle Survey

Definitions

Minor motor vehicle accident:

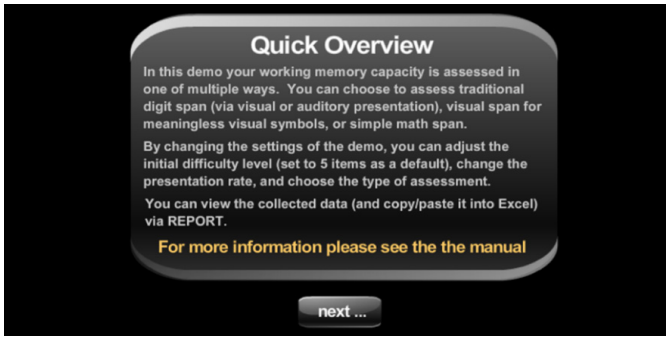
1) Driving high speeds over a speed bump
2) Frequently driving over Botts' dots [bumps between road lanes]

Major motor vehicle accident:

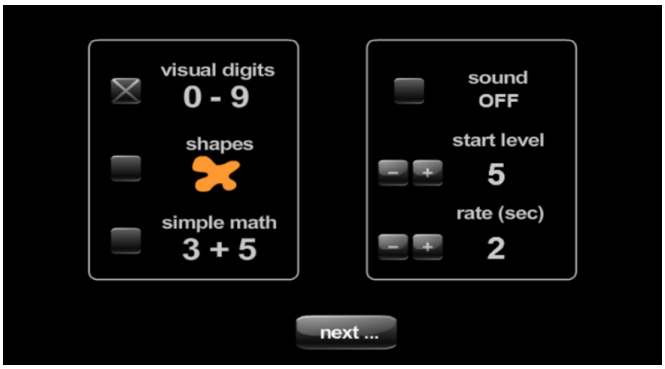
1) Direct contact or a near miss with another vehicle or object
2) A collision that resulted in damage to your vehicle

- After a normal work shift, how likely are you to be in a minor motor vehicle accident (when driving) [Very unlikely, Unlikely, Neutral, Likely, Very Likely]
- After a normal work shift, how likely are you to be in a major motor vehicle accident (when driving) [Very unlikely, Unlikely, Neutral, Likely, Very Likely]
- After an on-call shift, how likely are you to be in a minor motor vehicle accident (when driving) [Very unlikely, Unlikely, Neutral, Likely, Very Likely]
- After an on-call shift, how likely are you to be in a major motor vehicle accident (when driving) [Very unlikely, Unlikely, Neutral, Likely, Very Likely

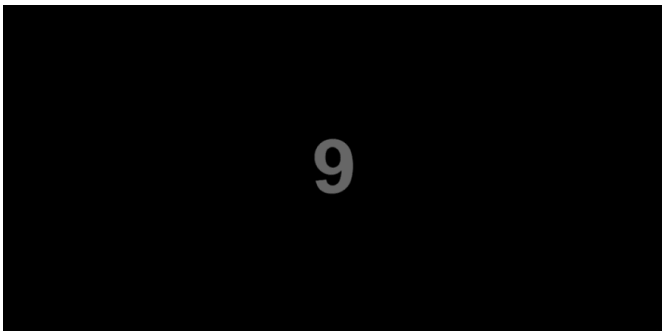
Appendix B: CoCognitive Software



a) Title Page



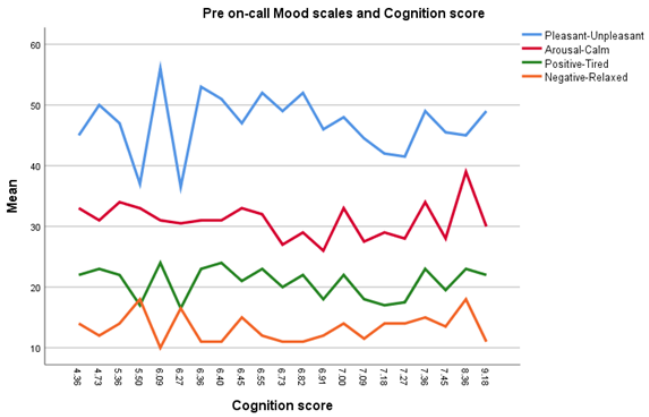
b) Options of various cognitive assessments and difficulties



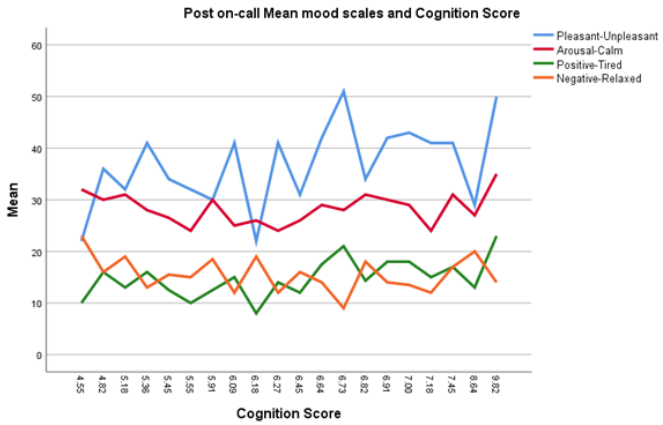
d) Example of a digit appearing on the screen

c) Participants need to click the numbers in the correct order in which the digits have appeared on the screen

Appendix C: Mean mood scales and Cognition Score Pre on-call



Appendix D: Mean mood scales and Cognition Score Post on-call



Appendix E: Mean mood scales and Cognition Score Normal shift