AWARD NUMBER: W81XWH-20-1-0442

TITLE: Resilience to Sleep Loss and Stress: A Framework for Investigation and Intervention

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REPORT DATE: October 2022

TYPE OF REPORT: Annual

PREPARED FOR: U.S. Army Medical Research and Development Command
Fort Detrick, Maryland 21702-5012

DISTRIBUTION STATEMENT: Approved for Public Release;
Distribution Unlimited

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE	**2. REPORT TYPE**	**3. DATES COVERED**
Oct 2022	Annual	15 Sept 2021 – 14 Sept 2022

4. TITLE AND SUBTITLE

Resilience to Sleep Loss and Stress: A Framework for Investigation and Intervention

5a. CONTRACT NUMBER
W81XWH-20-1-0442

5b. GRANT NUMBER
PR192166

5c. PROGRAM ELEMENT NUMBER

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5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S. Army Medical Research and Development Command
Fort Detrick, Maryland 21702-5012

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for Public Release; Distribution Unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Sleep loss and acute stress often occur simultaneously during military operations, but their combined effect on cognition – and therefore how to protect against any adverse effects – remains under-investigated. In this research project, we seek to develop a framework in which resilience to sleep loss and stress can be investigated separately and jointly. In a laboratory-based study, healthy young adults are assigned to one of four conditions: sleep deprivation only, stress only, combined sleep deprivation and stress, or control (no sleep deprivation or stress). Subjects' vigilant attention, working memory, cognitive flexibility, and dynamic risk awareness are tested twice: once immediately following a sham stress task during well-rested baseline, and again 24 h later, immediately following either a stress or sham stress task when subjects are either in a 39 h sleep deprivation or rested control condition. During this report period, we developed and finalized study procedures, began participant recruitment and screening, and completed data collection on the first 2 study participants. This work will allow us to develop a framework for the systematic investigation of the effect of sleep loss and stress on military operations, which will enable the development of targeted interventions that increase resilience against operational performance impairment.

15. SUBJECT TERMS
sleep deprivation, stress, performance impairment, attentional control, cognitive flexibility, mission success, resilience

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
					USAMRDC
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**		41	**19b. TELEPHONE NUMBER** *(include area code)*
Unclassified	Unclassified	Unclassified	Unclassified		

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1. INTRODUCTION

Sleep loss and acute stress are common during military operations, resulting in impaired situational awareness and decision making. Performance deficits due to sleep loss are increasingly understood to be the result of changes in the ability to adjust attentional control in fast-paced, dynamically changing circumstances. In contrast, less is known about the effect of stress on cognition or its combined effect with sleep loss. Despite the fact sleep loss and stress often co-occur during military operations, their combined effect on cognition – and therefore how to protect against any adverse effects – remain under-investigated. In this research project, we seek to develop a framework in which resilience to sleep loss and stress can be investigated separately and jointly. In a laboratory-based study, healthy young adults are assigned to one of four conditions: a sleep deprivation only condition, a stress only condition, a combined sleep deprivation and stress condition, or a control (no sleep deprivation or stress) condition. To investigate the separate and joint effects of sleep loss and stress on performance, subjects are tested on tasks specifically developed for this study that assess their vigilant attention, working memory, cognitive flexibility, and dynamic risk awareness. These tasks are administered twice: once following a sham stress task (i.e., a non-stressful variation on the stress task) while all subjects are at their well-rested baseline, and again 24 h later, following either the stress task or the sham stress task while half the subjects are assigned to a 39 h sleep deprivation condition and the other half are assigned to a well-rested control condition. By providing a framework for systematic investigation of the effect of sleep loss and stress on military operations, this research project will enable the development of targeted interventions that increase resilience against operational performance impairment. Further, this research project will help to improve the safety and success of millions of Americans, including US military personnel, who are frequently exposed to sleep loss and stress.

2. KEYWORDS

Sleep deprivation, stress, performance impairment, attentional control, cognitive flexibility, mission success, resilience

3. ACCOMPLISHMENTS

What were the major goals of the project?

Specific Aim 1: Test the prediction of the Dynamic Attention Control (DAC) framework that sleep deprivation (SD) without stress induction spares working memory (WM) capacity, but compromises (a) the establishment of choice outcome associations and (b) the binding and interference management processes needed for cognitive flexibility (CF).	**Timeline**	**Completed**
Study Preparations	Months	
Milestone(s) Achieved: Procedures documented and IRB/HRPO approvals obtained	1-3	1 Jul 2021
Data Collection		
Milestone(s) Achieved: Aim 1 data collection completed from 32 subjects (16 in a sleep deprivation condition and 16 in a no sleep deprivation and no stress condition)	4-30	in progress (delay incurred by COVID-19 laboratory closure)
Data Analysis		
Milestone(s) Achieved: Aim 1 analyses completed	5-33	n/a
Specific Aim 2: Test how the attentional control processes specified in the DAC framework are affected by stress induction without SD.		
Data Collection		
Milestone(s) Achieved: Aim 2 data collection completed from 32 subjects (16 in a stress condition and 16 in a no sleep deprivation and no stress condition)	4-30	in progress (delay incurred by COVID-19 laboratory closure)
Data Analysis		
Milestone(s) Achieved: Aim 2 analyses completed	5-33	n/a
Specific Aim 3: Determine how the joint effects of acute stress and SD impact attentional control, CF, and risky decision making.		
Data Collection		
Milestone(s) Achieved: Aim 3 data collection completed from 48 subjects (16 in a sleep deprivation condition; 16 in a stress condition; and 16 in a combined sleep deprivation and stress condition)	4-30	in progress (delay incurred by COVID-19 laboratory closure)
Data Analysis		
Milestone(s) Achieved: Aim 3 analyses completed	5-33	n/a

Final Report Preparation		
Compilation of analyses from aims 1–3 and drafting of report and briefing	34-36	n/a
Presentation of study results to the DoD	36	n/a
Milestone(s) Achieved: study completed	**36**	in progress

What was accomplished under these goals?

During Year 2, the major activities to be completed to achieve the goal milestones were:

- Continued ethical review of the study procedures by the Washington State University IRB and the DoD's HRPO – completed.

- Development of standard operating procedures for the study, including procedures for participant recruitment and screening, polysomnographic and actigraphic sleep recordings, Holter heart monitor hook-up and recording, cognitive task training and administration, saliva and blood collection and processing, skin conductance response hook-up and recording, behavioral monitoring, study setup, and data harvesting; and staff training (Aims 1-3) – completed.

- Finalizing procedures and staff training for conducting the stress task (and non-stressful sham task) that is administered prior to the cognitive battery used to assess elements of the DAC framework. To induce stress, we are using the Maastricht Acute Stress Test (MAST). The MAST combines physiological, mental, and psychological stress by having participants alternate between placing both their feet into ice cold water (~2°C) and counting backward from 2043 by intervals of 17 for 45–90 s in the presence of a stoically monitoring researcher. The MAST has been shown to elicit increases in subjective, autonomic, and glucocorticoid stress responses. In order to have a comparable control task from which to compare participants' stress responses to their own rested baseline as well as to those not in a stress condition, we also are using the sham (non-stressful) version of the MAST. In this version, participants alternate between putting their feet in lukewarm water (~35–37°C) and counting from 1 to 25 for 45–90 s. The sham MAST provides a comparable physical and psychological task without inducing subjective or objective stress responses. Because the stress response duration is limited (up to 60 min), the procedures for preparing and administering the stress and sham task, as well as the DAC cognitive task battery that immediately follows, have been well-tested to ensure they are conducted in a timely manner (Aims 1-3) – completed.

- Development and testing of the standard test battery that is administered at regular 2–3 h intervals throughout the study. This battery consists of the Karolinska Sleepiness Scale (KSS), the Positive and Negative Affect Schedule (PANAS), and the Psychomotor Vigilance Test (PVT). The KSS measures subjective sleepiness, with participants indicating their level of perceived sleepiness on a 1 (extremely alert) to 9 (very sleepy) scale. The PANAS is a subjective mood scale, with participants indicating the extent to which they are currently experiencing each of 10 positive and 10 negative emotions. The PVT is a serial reaction time task in which subjects respond as quickly as possible to a stimulus presented at random inter-stimulus intervals of 2–10 s. The PVT is a gold-standard measure of vigilant attention and is particularly sensitive to sleep loss – completed.

- Development and testing of the remaining cognitive tasks that participants complete during the study. These tasks include a sleep inertia test battery, which occurs immediately upon awakening, a morning task battery, and two afternoon task batteries. In the sleep inertia test battery, which assesses participants' cognitive abilities during the characteristic period of grogginess immediately after awakening, participants complete the KSS before and after completing a shortened version of an Operation Span task. These tests assess subjective sleepiness and the ability to hold information in working memory while completing simple arithmetic problems. In the morning task battery, participants complete a variant of the PVT. They also complete an N-back task (Day 2), which requires them to remember stimuli shown either 1 or 2 trials previously; a memory task that assesses how well individuals implicitly or explicitly remember information that they intentionally studied or were incidentally exposed to (Day 3); and a memory-for-text task that assesses their memory for longer narratives (Days 3 and 4). Broadly, this battery assesses the effect of sleep or sleep deprivation on participants' vigilant attention and memory. In the first afternoon task battery, participants complete the KSS, a mood scale, the PVT, and one of either the standard Digit Symbol Substitution Task (DSST), a memory version of the DSST, or a break of equivalent duration, before completing the PVT a second time. On the standard DSST, participants are shown symbols and must indicate, as quickly as possible, which digits they are associated with by using a digit-symbol pairing key presented at the top of the screen. On the memory version of the DSST, participants are shown symbols and must indicate its associated digit, but the full digit-symbol pairing key is not presented; rather, the associated digit-symbol pair is shown on the first presentation of the symbol and will not reappear unless the participant makes an error. This battery assesses features of the time-on-task effect on participants' cognitive ability while either rested or sleep deprived. In the second afternoon task battery, participants complete a memory task that tests their ability to remember pieces of information together and another variant of the PVT. This battery assesses the effect of sleep or sleep deprivation on a different aspect of memory and vigilant attention. Participants also complete a procedural/declarative memory task, a standard vigilant attention task, a test of their fluid and crystallized intelligence, a social desirability scale, and a memory task testing their ability to remember pieces of information and the context in which the information was originally presented – completed.

- A minor IRB amendment was submitted and approved to modify procedures as the study preparations were adapted and finalized (Aims 1-3) – completed.

- In-laboratory "dry runs" were conducted, with laboratory staff acting as "study participants" for portions of the study protocol, to practice the timing and execution of study procedures (Aims 1-3) – completed.

- Dissemination of advertising materials and initialization of participant screening (Aims 1-3) – completed.

- Scheduling of initial study runs (Aims 1-3) – completed.

- Two participants have completed data collection (Aims 1-3).

Summary of the laboratory study protocol:
Carefully screened, healthy young adults are randomized to one of four conditions (target N = 16 in each condition): a sleep deprivation only condition; a stress only condition; a combined sleep deprivation and stress condition; or a control (no sleep deprivation and no stress) condition (see Table 1). Subjects are in the laboratory for four days/three nights continuously, under constant observation and physiological monitoring. In either of the two sleep deprivation conditions (sleep deprivation only or combined sleep deprivation and stress), subjects have one night with 9 h time in bed for baseline sleep, then undergo 39 h of total sleep deprivation (equivalent to missing one night of sleep), and finally are given one recovery night with 9 h time in bed for sleep. Those in the stress only or control conditions have 9 h in bed for sleep on all three nights. Subjects sleep is recorded polysomnographically and actigraphically during all scheduled sleep periods.

Subjects are tested on a range of cognitive performance tasks at baseline, and 24 h later after sleep deprivation (or well-rested control). At baseline, all subjects complete the battery of tasks following a sham version of a stress test. Following the night of either sleep deprivation or rest, those in the two stress conditions (stress only or combined sleep deprivation and stress) complete the battery of tasks following a stress test. Those in the other two conditions again complete the battery following the sham version of the stress test. During the task battery, subjects' skin conductance responses (SCR) are recorded using disposable self-adhesive electrodes attached to the non-dominant hand on the intermediate phalange of the index and middle fingers. Saliva samples are collected approximately every 15 minutes from the beginning of the stress or sham stress test to the end of the task battery and approximately every 2-3 h throughout the study. Additionally, venous whole blood is collected from each subject after the completion of the battery. The cognitive tests and physiological measures obtained during the study will serve to test the prediction of the Dynamic Attention Control (DAC) framework that sleep deprivation without stress induction spares working memory capacity, but compromises (a) the establishment of choice outcome associations and (b) the binding and interference management processes needed for cognitive flexibility; test how the attentional control processes specified in the DAC framework are affected by stress induction without sleep deprivation; and determine how the joint effects of acute stress and sleep deprivation impact attentional control, cognitive flexibility, and risky decision making.

Table 1. Matrix of study conditions.

		Sleep Deprivation?	
		Yes	No
Stress?	Yes	**N=16** Sleep Dep + Stress	**N=16** Stress Only
	No	**N=16** Sleep Dep Only	**N=16** Neither (control)

Stated goals not met:

Due to delays and laboratory closures caused by the COVID-19 pandemic in year 1, we began year 2 considerably behind schedule. During year 2, we were able to develop and test the study procedures, train staff, and begin recruitment for the study. While we are attempting to accelerate subject recruitment and have successfully begun data collection, with more participants scheduled for upcoming study runs occurring in year 3, recruitment overall has been slow, limiting the number of participants who could be screened for eligibility in the study. Additionally, by necessity, availability of the laboratory has been shared with another DoD-funded in-laboratory study, which has also been delayed by the pandemic. Together, these pandemic-related constraints have left us behind schedule for studying subjects in the laboratory (Aims 1–3). We are carefully monitoring our funding and pacing expenditures in proportion to project effort, so that we can finish the project in the (likely) event that a 1-year no-cost extension may be needed.

What opportunities for training and professional development has the project provided?

The project provides significant opportunities for postdoctoral and graduate education and professional development:

- A former postdoctoral researcher in the Department of Psychology, now a Research Assistant Professor in the Department of Translational Medicine and Physiology at Washington State University, Courtney Kurinec, is intensively involved in this project. She receives training in the management and development of sleep deprivation studies; preparing reports for government stakeholders; grant writing; programming of cognitive performance tasks in E-Prime software; and data reduction and statistical analysis. She is involved in the project under the direct mentorship of the PI and Co-PIs of the project. During Year 2, her work related to this project has been presented at an international and a national conference on sleep science.

- A Ph.D. student in the Experimental Psychology graduate program at Washington State University, Amanda Hudson, has been involved in this project to develop and program novel cognitive tasks to assess performance changes during sleep deprivation and/or stress. She is currently receiving training in recording of sleep (polysomnography); recording and processing of galvanic skin conductance; developing and programming of cognitive performance tasks in E-Prime software; and data reduction and statistical analysis. The graduate student is involved in the project under the direct mentorship of one of the Co-PIs of the project, Dr. Kimberly Honn, and training and experience has been gained on a daily basis. During Year 2, the graduate student worked with the investigators to develop study procedures and tasks for the study and presented her research related to this project at a national sleep science conference.

- A Ph.D. student in the Experimental Psychology graduate program at Washington State University, Anthony Stenson, has been involved in the development of several of the cognitive performance tests in this project. He is receiving training on the programming of cognitive performance tasks in E-Prime software; data reduction and statistical analysis; cognitive model development; and manuscript writing. The graduate student is involved in the project under the direct mentorship of two Co-PIs of the project, Drs. Paul Whitney and John Hinson. During Year 2, the graduate student worked with the investigators to develop study procedures and tasks for the study.

- A Ph.D. student in the Experimental Psychology graduate program at Washington State University, Emily Moslener, has been involved in this project to develop and program novel cognitive tasks to assess performance changes during sleep deprivation and/or stress. She is receiving training in recording and processing of galvanic skin conductance; developing and programming of cognitive performance tasks in E-Prime software; and data reduction and statistical analysis. The graduate student is involved in the project under the direct mentorship of one of the Co-PIs of the project, Dr. Kimberly Honn, and training and experience has been gained on a daily basis. During Year 2, the graduate student worked with the investigators to develop study procedures and tasks for the study and presented her research related to this project at a national sleep science conference.

- A Ph.D. student in the Experimental Psychology graduate program at Washington State University, Kirsie Lundholm, has been involved in this project to help develop the study procedures involved in the stress task and the associated saliva samples and processing. She is receiving training in saliva sampling and processing; blood sampling and processing; developing and programming of cognitive performance tasks in E-Prime software; stress test implementation; protocol development; data reduction; and statistical analysis. The graduate student is involved in the project under the direct mentorship of one of the Co-PIs of the project, Dr. Kimberly Honn, and training and experience has been gained on a daily basis. During Year 2, the graduate student worked with the investigators to develop study procedures and tasks for the study and train research assistants on saliva collection and other task procedures.

How were the results disseminated to communities of interest?

The results were shared with relevant military and civilian communities through presentations at the 2022 World Sleep and SLEEP conferences as well as the US DoD-initiated MQ Military Biomarker Symposium in Australia and a DARPA Forward conference.

What do you plan to do during the next reporting period to accomplish the goals?

Now that the study is actively collecting data, year 3 will be fully focused on subject recruitment, screening, and data collection in the laboratory experiment. Our goal is to have completed data collection by the end of Year 3. However, as noted above, pandemic-related delays may eventually necessitate a 1-year no-cost extension, and we are carefully monitoring our expenditures to make sure sufficient resources will be available to finish the project in that instance. That being said, we are increasing our study advertising efforts and continue working to accelerate the pace of subject recruitment. We have recently hired 4 additional full-time staff members to facilitate recruitment and screening.

Some of the data collected during Year 3 of the study will be available for preliminary analyses, which will be used in training opportunities for graduate students and post-baccalaureate students and presented at national conferences for dissemination.

4. IMPACT

What was the impact on the development of the principal discipline(s) of the project?

During the pandemic-based period of laboratory closure, we performed analyses of archival data related to the project to keep the relevant science moving forward. In a paper published in the journal *Clocks & Sleep* and presented at the SLEEP 2022 conference (Charlotte, NC), we showed that contrary to widespread belief, after controlling for a range of potential confounds there was no evidence for endogenous task-dependent differences in the optimal circadian timing of performance and alertness. This new information is relevant in military operations, in that scheduling different tasks at different times of day in the belief that each task has an optimal circadian timing may not have the desired effect.

In a conference abstract presented at the SLEEP 2022 conference, we found that individual differences in fluid intelligence do not moderate sleep deprivation-induced deficits on the Digit Symbol Substitution Test. Relatedly, in a conference abstract presented at World Sleep 2022, we found that higher fluid intelligence benefitted speed of semantic decision processing even when subjects were sleep deprived, but higher fluid intelligence only benefitted performance on a cognitive flexibility task when subjects were rested. These findings are relevant to research efforts to identify pre-existing individual differences that convey resilience to sleep loss.

Our other conferences abstracts presented at SLEEP 2022 investigated the impact of sleep loss on other aspects of cognitive performance. First, we found that sleep deprivation exacerbated deficits on a continuous performance matching task that required subjects to indicate whether the displayed 3-digit number was identical to the one previously shown, especially when the displayed number had high stimulus overlap with the previous number. This work suggests that sleep loss may intensify the costs associated with managing stimulus conflict.

Second, we found that pairs of words that were unitized, or presented as a new compound word, were better remembered during sleep deprivation compared to pairs of words that were presented individually. This finding indicates that unitizing stimuli may mitigate the impairing effect of sleep deprivation on associative memory, which could ultimately lead to a novel countermeasure approach.

Third, on a computerized shooting task where subjects were given hints of varying accuracy to facilitate their performance, sleep deprivation impaired performance; additionally, all subjects appeared to disregard the hints after they were no longer 100% predictive of the targets. This work indicates that even though sleep loss may worsen target accuracy, both rested and sleep deprived individuals ignore helpful background information if it is not completely reliable. If this generalizes to military operations (which we have yet to demonstrate), the implications would be significant.

Finally, we found that subjects higher in social desirability report lower subjective sleepiness than those with average social desirability, even when both groups show similar levels of objective sleepiness. This finding suggests that a challenge for fatigue risk management is that individuals may underreport their sleepiness in order to appear more favorable to others. Potential implications for the DoD community are self-evident.

What was the impact on other disciplines?

Nothing to Report.

What was the impact on technology transfer?

Nothing to Report.

What was the impact on society beyond science and technology?

In both military and civilian environments, sleep loss and stress increase the chances of errors and accidents, increasing the likelihood of injury and death and undermining the chances of mission success. Although there have been advances in understanding how sleep loss affects the mechanisms underlying effective performance, situational awareness, and decision making, it remains to be determined how stress impacts these abilities, as well as what the joint effects of stress and sleep loss may be. This project will provide a single framework for explaining the separate and joint effects of sleep loss and stress on decision making in dynamic environments, which will serve to guide the development of future countermeasures.

5. CHANGES/PROBLEMS

Changes in approach and reasons for change

Nothing to Report.

Actual or anticipated problems or delays and actions or plans to resolve them

We have incurred considerable delays due to the COVID-19 pandemic, which forced us to shut down our laboratory from March 2020 until September 2021. Furthermore, availability of the laboratory has had to be shared with another DoD-funded in-laboratory study, which has also been delayed by the pandemic. Consequently, we are behind schedule with regard to subject enrollment for the in-laboratory study of this project. Now that we have been able to reopen our laboratory and resume research activities, we have intensified our efforts to conduct this study. That said, it is anticipated that we will eventually need to request a 1-year no-cost extension to be able to fully meet our objectives.

Changes that had a significant impact on expenditures

Due to the impact of COVID-19 and the associated laboratory closure and study recruitment delays, we are behind schedule with regard to studying subjects in the laboratory. Expenditures are therefore lagging compared to the original budget. We expect that the difference will dissipate as we accelerate the pace of the study to complete data collection. We are however carefully monitoring our funding and pacing expenditures so as to be able to finish the project in the event a 1-year no-cost extension is needed.

Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents

Nothing to Report.

Significant changes in use or care of human subjects

Nothing to Report.

Significant changes in use or care of vertebrate animals.

Nothing to Report (Not Applicable).

Significant changes in use of biohazards and/or select agents

Nothing to Report (Not Applicable).

6. PRODUCTS

<u>Publications, conference papers, and presentations</u>

Journal publications

Muck R. A., Hudson A. N., Honn K. A., Gaddameedhi S., & Van Dongen H. P. A. Working around the clock: Is a person's endogenous circadian timing for optimal neurobehavioral functioning inherently task-dependent? *Clocks & Sleep*, 2022; 4(1):23-36, published. Acknowledgement of federal support: yes.

Books or other non-periodical, one-time publications

Ph.D. dissertations:

Nothing to Report.

Conference abstracts:

Honn, K., Kurinec, C., Hinson, J., Whitney, P., & Van Dongen, H. Fluid intelligence does not mediate cognitive throughput deficits during total sleep deprivation. *Sleep*, 2022, 45 (Supplement 1): A56, published. Acknowledgement of federal support: yes.

Hudson, A., Hinson, J., Whitney, P., Lawrence-Sidebottom, D., Van Dongen, H., & Honn, K. Effects of total sleep deprivation on performance on a continuous performance matching task. *Sleep*, 2022, 45 (Supplement 1): A53, published. Acknowledgement of federal support: yes.

Kurinec, C., Stenson, A., Hinson, J., Whitney, P., Honn, K., Van Dongen, H. Examining premorbid cognitive abilities to predict task-specific, inter-individual differences in resilience to total sleep deprivation. *Sleep Medicine*, 2022, 100, S31-S32, published. Acknowledgement of federal support: yes.

Kurinec, C., Whitney, P., Hinson, J., Satterfield, B., Honn, K., & Van Dongen, H. Unitization improves memory for associations during sleep deprivation. *Sleep*, 2022; 45 (Supplement 1): A48, published. Acknowledgement of federal support: yes.

Moslener, E., & Honn, K. Performance on a computerized threat elimination task in an animated environment during total sleep deprivation. *Sleep*, 2022, 45 (Supplement 1): A53, published. Acknowledgement of federal support: yes.

Muck, R., Hudson, A., Honn, K., & Van Dongen, H. Is the timing of the endogenous circadian rhythm of neurobehavioral functioning inherently task-dependent? *Sleep*, 2022, 45 (Supplement 1): A99, published. Acknowledgement of federal support: yes.

Scott, J., Muck, R., Van Dongen, H., & Honn, K. Social desirability mediates self-reported sleepiness during a laboratory total sleep deprivation study. *Sleep*, 2022, 45 (Supplement 1): A131, published. Acknowledgement of federal support: yes.

Other publications, conference papers, and presentations

Invited lectures:

Van Dongen, H. P. A. Impact of sleep deprivation on cognitive flexibility and emotional control. World Sleep 2022 conference (Rome, Italy). March 2022.

Van Dongen, H. P. A. Concepts and strategies for addressing sleep, fatigue, and burnout. SLEEP 2022 conference (Charlotte, NC). June 2022.

Van Dongen, H. P. A. Harnessing multi-modal functional measurements and biomarker assessments to predict the temporal dynamics of sleep loss-induced performance impairment. MQ Military Biomarker Symposium, Macquarie University (Sydney, Australia). June 2022.

Van Dongen, H. P. A. Resilience to performance deficits from sleep loss: Grand challenge for measurement, prediction, and intervention. DARPA Forward conference (Pullman, Washington). September 2022.

Oral presentations at conferences:

Honn, K., Kurinec, C., Hinson, J., Whitney, P., & Van Dongen, H. Fluid intelligence does not mediate cognitive throughput deficits during total sleep deprivation. Oral presentation at the SLEEP 2022 conference (Charlotte, NC). June 2022.

Kurinec, C., Whitney, P., Hinson, J., Satterfield, B., Honn, K., & Van Dongen, H. Unitization improves memory for associations during sleep deprivation. Oral presentation at the SLEEP 2022 conference (Charlotte, NC). June 2022.

Moslener, E., & Honn, K. Performance on a computerized threat elimination task in an animated environment during total sleep deprivation. Oral presentation at the SLEEP 2022 conference (Charlotte, NC). June 2022.

Website(s) or other Internet site(s)

Nothing to Report.

Technologies or techniques

Nothing to Report.

Inventions, patent applications, and/or licenses

Nothing to Report.

Other Products

Nothing to Report.

7. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

What individuals have worked on the project?

Name:	*Hans P.A. Van Dongen, Ph.D.*
Project Role:	*PI*
Researcher Identifier:	*ORCID ID: 0000-0002-4678-2971*
Nearest person month worked:	*2*
Contribution to Project:	*Dr. Van Dongen oversaw the project and coordinated all personnel activities and tasks.*
Funding Support:	

Name:	*Kimberly A. Honn, Ph.D.*
Project Role:	*Co-PI*
Researcher Identifier:	*ORCID ID: 0000-0001-8911-6277*
Nearest person month worked:	*1*
Contribution to Project:	*Dr. Honn oversaw the development of study procedures and the training of staff.*
Funding Support:	

Name:	*Paul Whitney, Ph.D.*
Project Role:	*Co-PI*
Researcher Identifier:	*ORCID ID: 0000-0003-1973-5261*
Nearest person month worked:	*1*
Contribution to Project:	*Dr. Whitney contributed key expertise on the development of measures in the cognitive task batteries.*
Funding Support:	

Name:	*John M. Hinson, Ph.D.*

Project Role:	*Co-PI*
Researcher Identifier:	*ORCID ID: 0000-0002-5012-5974*
Nearest person month worked:	*1*
Contribution to Project:	*Dr. Hinson contributed critical expertise the development of measures in the cognitive task batteries as well as the development of the stress task.*
Funding Support:	

Name:	*Courtney A Kurinec, Ph.D.*
Project Role:	*Postdoctoral Researcher*
Researcher Identifier:	*ORCID ID: 0000-0001-5800-1610*
Nearest person month worked:	*4*
Contribution to Project:	*Dr. Kurinec assisted Dr. Honn with the development of study procedures and contributed to the development of measures in the cognitive task batteries.*
Funding Support:	

Name:	*Matthew E. Layton, M.D., Ph.D.*
Project Role:	*Physician of Record*
Researcher Identifier:	*ORCID ID: 0000-0002-3287-9203*
Nearest person month worked:	*1*
Contribution to Project:	*Dr. Layton served as medical director for the study and implemented procedures for the participant screening.*
Funding Support:	

Name:	*Dawn DePriest, Ph.D., FNP-C*
Project Role:	*Medical Oversight*
Researcher Identifier:	*Washington State University ID: 11458230*
Nearest person month worked:	*1*
Contribution to Project:	*Together with Dr. Layton, Dr. DePriest performed medical exams during screening and oversaw subject health and well-being in the laboratory study.*
Funding Support:	

Name:	*Sue Weeks, MN, FNP-C, PMHNP-BC, DNP*
Project Role:	*Medical Oversight*
Researcher Identifier:	*Washington State University ID: 11458230*
Nearest person month worked:	*1*
Contribution to Project:	*Together with Dr. Layton, Dr. Weeks performed medical exams during screening and oversaw subject health and well-being in the laboratory study.*
Funding Support:	

Name:	*Naomi Teeter, M.S.*
Project Role:	*Research Coordinator*
Researcher Identifier:	*Washington State University ID: 11792273*
Nearest person month worked:	1
Contribution to Project:	*Ms. Teeter assisted with scheduling research assistants, obtaining informed consent, and overseeing the laboratory study.*
Funding Support:	

Name:	*Myles Finlay, RPSGT*
Project Role:	*Registered Polysomnographic Technologist*
Researcher Identifier:	*Washington State University ID: 11546225*
Nearest person month worked:	1
Contribution to Project:	*Mr. Finlay oversaw sleep monitoring in the laboratory study, including assessment of baseline sleep to verify inclusion criteria. He also trained research assistants and graduate students on sleep recording procedures.*
Funding Support:	

Name:	*Amanda Hudson, M.A.*
Project Role:	*Ph.D. Student*
Researcher Identifier:	*ORCID ID: 0000-0002-1641-1782*
Nearest person month worked:	*2*
Contribution to Project:	*Ms. Hudson developed study procedures and implemented performance testing for the study.*
Funding Support:	

Name:	*Anthony Stenson, M.A.*
Project Role:	*Ph.D. Student*
Researcher Identifier:	*ORCID ID: 0000-0002-2405-0649*
Nearest person month worked:	*1*
Contribution to Project:	*Mr. Stenson assisted with the development of measures in the cognitive task batteries.*
Funding Support:	*National Science Foundation award #1840192*

Name:	*Emily Moslener, B.A.*
Project Role:	*Ph.D. Student*
Researcher Identifier:	*ORCID ID:* 0000-0002-8034-3139
Nearest person month worked:	*2*
Contribution to Project:	*Ms. Moslener developed study procedures and implemented performance testing for the study.*
Funding Support:	

Name:	*Kirsie Lundholm, B.S.*
Project Role:	*Ph.D. Student*
Researcher Identifier:	*ORCID ID:* 0000-0002-8191-2508
Nearest person month worked:	*4*
Contribution to Project:	*Ms. Lundholm developed study procedures and oversaw training on saliva collection and processing. She also assisted with development of the stress task procedures and minute-by-minute study protocol.*
Funding Support:	

Name:	*Lillian Skeiky, M.S.*
Project Role:	*Ph.D. Student*
Researcher Identifier:	*Washington State University ID: 11656455*
Nearest person month worked:	*4*
Contribution to Project:	*Ms. Skeiky assisted with blood draws during screening and study procedures, blood and saliva processing, and laboratory study data collection.*
Funding Support:	

Name:	*Rachael Muck, B.S.*
Project Role:	*M.S. Student*
Researcher Identifier:	*Washington State University ID: 11441657*
Nearest person month worked:	*4*
Contribution to Project:	*Ms. Muck assisted with blood draws during screening and study procedures, blood and saliva processing, and laboratory study data collection.*
Funding Support:	

Name:	*Sofia Fluke, B.S.*
Project Role:	*Ph.D. Student*
Researcher Identifier:	*Washington State University ID: 11726590*
Nearest person month worked:	*4*
Contribution to Project:	*Ms. Fluke assisted with laboratory study data collection.*
Funding Support:	

Name:	*Mariana Pacheco-Arcaya*
Project Role:	*Research Assistant*
Researcher Identifier:	*Washington State University ID: 11803213*
Nearest person month worked:	1
Contribution to Project:	*Ms. Pacheco-Arcaya was part of the group of research assistants providing around-the-clock staffing and carrying out the research protocol for the laboratory study. She also assisted with screenings and meal preparations for the study.*
Funding Support:	

Name:	*Anthony Scholes*
Project Role:	*Research Assistant*
Researcher Identifier:	*Washington State University ID: 11812127*
Nearest person month worked:	1
Contribution to Project:	*Mr. Scholes was part of the group of research assistants providing around-the-clock staffing and carrying out the research protocol for the laboratory study. He also assisted with recruitment, screenings, and study preparations.*
Funding Support:	

Name:	*Rebecca Simmons*
Project Role:	*Research Assistant*
Researcher Identifier:	*Washington State University ID: 11792459*
Nearest person month worked:	1
Contribution to Project:	*Ms. Simmons was part of the group of research assistants providing around-the-clock staffing and carrying out the research protocol for the laboratory study. She also assisted with recruitment, screenings and study preparations.*
Funding Support:	

Name:	*Jiayi Ena Wang*
Project Role:	*Research Assistant*
Researcher Identifier:	*Washington State University ID: 11696023*
Nearest person month worked:	*1*
Contribution to Project:	*Ms. Wang was part of the group of research assistants providing around-the-clock staffing and carrying out the research protocol for the laboratory study. She also assisted with screenings and preparations for the study.*
Funding Support:	

Name:	*Tye Arrington-Fox*
Project Role:	*Research Assistant*
Researcher Identifier:	*Washington State University ID: 11791760*
Nearest person month worked:	1
Contribution to Project:	*Mr. Arrington-Fox was part of the group of research assistants providing around-the-clock staffing and carrying out the research protocol for the laboratory study.*
Funding Support:	

Name:	*Anthony Bennett*
Project Role:	*Research Assistant*
Researcher Identifier:	*Washington State University ID: 11814077*
Nearest person month worked:	1
Contribution to Project:	*Mr. Bennett was part of the group of research assistants providing around-the-clock staffing and carrying out the research protocol for the laboratory study.*
Funding Support:	

Name:	*Blake Budke*
Project Role:	*Research Assistant*
Researcher Identifier:	*Washington State University ID: 11588945*
Nearest person month worked:	1
Contribution to Project:	*Mr. Budke was part of the group of research assistants providing around-the-clock staffing and carrying out the research protocol for the laboratory study.*
Funding Support:	

Name:	*Sara Delane*
Project Role:	*Research Assistant*
Researcher Identifier:	*Washington State University ID: 11622588*
Nearest person month worked:	1
Contribution to Project:	*Ms. Delane was part of the group of research assistants providing around-the-clock staffing and carrying out the research protocol for the laboratory study.*
Funding Support:	

Name:	*Ashlyn Kovacevich*
Project Role:	*Research Assistant*
Researcher Identifier:	*Washington State University ID: 11819440*
Nearest person month worked:	1
Contribution to Project:	*Ms. Kovacevich was part of the group of research assistants providing around-the-clock staffing and carrying out the research protocol for the laboratory study.*
Funding Support:	

Name:	*Shen Tsao*
Project Role:	*Research Assistant*
Researcher Identifier:	*Washington State University ID: 11513719*
Nearest person month worked:	1
Contribution to Project:	*Ms. Tsao was part of the group of research assistants providing around-the-clock staffing and carrying out the research protocol for the the laboratory study.*
Funding Support:	

Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?

Nothing to Report.

What other organizations were involved as partners?

Nothing to Report.

8. SPECIAL REPORTING REQUIREMENTS

Award Chart is enclosed (see Appendices).

9. APPENDICES

The following items are enclosed:

- Award Chart for 15 Sept 2021 – 14 Sept 2022
- PDF copy of Muck et al. (2022), *Clocks & Sleep* publication

Journal publications

Muck R. A., Hudson A. N., Honn K. A., Gaddameedhi S., & Van Dongen H. P. A. Working around the clock: Is a person's endogenous circadian timing for optimal neurobehavioral functioning inherently task-dependent? *Clocks & Sleep*, 2022; 4(1):23-36, published. Acknowledgement of federal support: yes.

See appendix for a PDF copy

Conference abstracts

Honn, K., Kurinec, C., Hinson, J., Whitney, P., & Van Dongen, H. Fluid intelligence does not mediate cognitive throughput deficits during total sleep deprivation. *Sleep*, 2022, 45 (Supplement 1): A56, published. Acknowledgement of federal support: yes.

0125

FLUID INTELLIGENCE DOES NOT MEDIATE COGNITIVE THROUGHPUT DEFICITS DURING TOTAL SLEEP DEPRIVATION

Kimberly Honn[1], Courtney Kurinec[1], John Hinson[2], Paul Whitney[2], Hans Van Dongen[1]

Washington State University Spokane [1] Washington State University [2]

Introduction: The Digit Symbol Substitution Test (DSST) has been used in sleep research to measure slowing of cognitive throughput. The task shows large aptitude differences in baseline performance and substantial inter-individual differences in vulnerability to performance deficits during total sleep deprivation (TSD). Fluid intelligence (Gf) is generally positively related to processing speed. However, DSST performance is typically found to be independent of Gf. The possible interaction of sleep loss with Gf on performance remains to be examined.

Methods: N=56 healthy adults (ages 22–37, 29 females) completed a 4-day/3-night in-laboratory study and were randomly assigned (2:1 ratio) to a TSD (n=37) or control (n=19) condition. Sleep opportunities were from 22:00–08:00 on the first (baseline) and last (recovery) night for the TSD group and on all three nights for the control group. Subjects completed a 4min, computerized DSST twice on day 2 (baseline) and twice on day 3 (TSD or control). At baseline, subjects also completed the Shipley Institute of Living Scale (SILS). The abstraction score was used to categorize fluid intelligence (Gf) as relatively high (≥34, n=36) or low (<34, n=20). Mean DSST throughput (number of correct responses in the 4min task) was analyzed using mixed-effects ANOVA with fixed effects for day (2, 3), condition (TSD, control), and their interaction, with and without Gf category (high, low) as a covariate.

Results: As expected, DSST throughput was significantly reduced by TSD (day by condition interaction: $F[1,166]=27.99$, $p<0.001$). Adding Gf had no effect on the day by condition interaction, and Gf category was not significant as a covariate ($F[1,166]=1.67$, $p=0.20$).

Conclusion: Our results indicate that the Gf measure from the SILS does not capture the aspects of cognition that are influenced by TSD and that lead to a decline in DSST throughput. This is consistent with findings that while the DSST has high sensitivity for cognitive dysfunction in clinical settings, it has low specificity in identifying components of cognition responsible for dysfunction.

Support (If Any): ONR N00014-13-1-0302 and PRMRP W81XWH-20-1-0442.

Hudson, A., Hinson, J., Whitney, P., Lawrence-Sidebottom, D., Van Dongen, H., & Honn, K. Effects of total sleep deprivation on performance on a continuous performance matching task. *Sleep*, 2022, 45 (Supplement 1): A53, published. Acknowledgement of federal support: yes.

0119

EFFECTS OF TOTAL SLEEP DEPRIVATION ON PERFORMANCE ON A CONTINUOUS PERFORMANCE MATCHING TASK

Amanda Hudson[1], John Hinson[2], Paul Whitney[2], Darian Lawrence-Sidebottom[3], Hans Van Dongen[1], Kimberly Honn[1]
Sleep and Performance Research Center [1] Washington State University [2] Naval Postgraduate School [3]

Introduction: Tasks requiring individuals to identify specific stimuli may create response/non-response conflict, which may impair performance depending on stimulus feature overlap. Whether sleep deprivation interacts with such impairment is unknown. We investigated the effects of total sleep deprivation (TSD) on stimulus identification in a continuous performance matching task (CPMT).

Methods: N=85 adults (ages 21–40; 50f) completed a 4-day laboratory study with 10h baseline sleep (22:00–08:00), a 38h acute TSD or 10h sleep opportunity (control condition), and 10h recovery sleep. The ~6min CPMT was administered every 2–4h during wakefulness. Participants completed 300 trials where a 3-digit number was flashed on the screen for 100ms. They were instructed to respond (mouse-click) within 900ms, but only if the number was the same as the preceding number (i.e., a repeat); for all other trials a response was to be withheld. The 5 daytime testing sessions (09:00–21:00) at baseline (day 2) and after TSD/control (day 3) were used for analysis. Trials were classified based on number of digits matching the preceding trial (stimulus feature overlap): none (180 trials), one (30 trials), two (near-repeat; 30 trials), or all (repeat; 60 trials). Hit and false alarm (FA) rates were analyzed with mixed-effects ANOVA for day, condition, trial type, and their interactions. Mean response time (MRT) was analyzed equivalently for repeat trials only.

Results: Hit rate declined from day 2 to day 3 in the TSD group ($F[1,83]=0.15$, $p<0.001$), but not the control group ($F[1,83]=0.018$, $p=0.335$). Though FA rate was low overall (<0.06), FA frequency was higher on trials with greater stimulus feature overlap. FA rate increased on day 3 for the TSD group (all $p<0.004$), especially for near-repeats ($F[1,415]=-0.014$, $p<0.001$). Changes in MRT were statistically significant, but negligible (<20ms).

Conclusion: Our results suggest that greater stimulus feature overlap on the CPMT was associated with greater costs required to resolve conflict. Sleep deprivation exacerbated these costs. Interpretation is limited however, because a response was not required for non-repeat trials. Implementing a two-alternative forced choice version of the task in future TSD studies would address this limitation.

Support (If Any): PRMRP W81XWH-16-1-0319 and W81XWH-20-1-0442

Kurinec, C., Stenson, A., Hinson, J., Whitney, P., Honn, K., Van Dongen, H. Examining premorbid cognitive abilities to predict task-specific, inter-individual differences in resilience to total sleep deprivation. *Sleep Medicine*, 2022, 100, S31-S32, published. Acknowledgement of federal support: yes.

EXAMINING PREMORBID COGNITIVE ABILITIES TO PREDICT TASK-SPECIFIC, INTER-INDIVIDUAL DIFFERENCES IN RESILIENCE TO TOTAL SLEEP DEPRIVATION

C. Kurinec [1], A. Stenson [1], J. Hinson [1], P. Whitney [1], K. Honn [2], H. Van Dongen [2]. [1] *Washington State University, Pullman, United States;* [2] *Washington State University, Spokane, United States*

Introduction: Resilience to cognitive impairment from total sleep deprivation (TSD) is task-specific, such that impairment on one task does not generally predict impairment on other tasks. This task-specificity may be, at least in part, a reflection of premorbid differences in cognitive abilities and the cognitive requirements of the tasks. We compared the extent to which premorbid differences in fluid intelligence (Gf) predict resilience to TSD for task performance involving speed of processing, known to be strongly related to Gf, versus cognitive flexibility, which is less strongly related to Gf.
Materials and Methods: Published data from a 4-day/3-night, in-laboratory study (N=47 healthy adults, ages 22–40; 26 men) were reexamined based on individual differences in Gf. After a baseline sleep opportunity, subjects were randomized to 38h TSD or well-rested control (WRC), which was followed by recovery sleep. Sleep opportunities were 10h (22:00–08:00). After baseline sleep (session 1) and 24h later (session 2), subjects completed two criterial tasks: the stimulus onset asynchrony semantic matching task (SM), which measures speed of access to word meanings and speed of decision processes, and the go/no-go reversal learning task (GNGr), which measures cognitive flexibility. We originally found TSD affected only speed of decision processes on the SM (Honn et al., 2018) and particularly impaired discriminability in the two post-reversal test blocks on the GNGr (Satterfield et al., 2018); these measures served as dependent variables. At baseline, subjects completed the Shipley Institute of Living Scale, which measures Gf; the abstraction score was used to categorize premorbid Gf as relatively high (≥34; WRC n=14, TSD n=14) or low (<34; WRC n=9, TSD n=10). Task performance was analyzed using mixed-effects ANOVAs with fixed effects of session, condition, and Gf-group and their interactions, and a random effect over subjects on the intercept; the GNGr analysis also included fixed effects of post-reversal test block and its interactions.
Results: TSD degraded session 2 performance on the SM, as evidenced by a condition by session interaction ($p< 0.001$). We also observed an effect of Gf-group ($p<0.001$). The expected benefit of Gf to speed of processing on the SM was observed regardless of session or condition.
TSD also degraded session 2 performance on the GNGr, whereas subjects in the WRC showed performance improvement in session 2 (condition by session interaction, $p=0.006$). Furthermore, there was a session by Gf-group by block interaction ($p=0.048$). Those with relatively high Gf improved across sessions on the second block ($p=0.037$), but this was evident only in rested subjects ($p<0.001$).
Conclusions: Premorbid Gf predicted sleep-deprived performance on a task conceptually related to Gf, such that the benefit of Gf to speed of semantic decision processing persisted across sessions. Regarding cognitive flexibility, higher Gf did not confer resilience to TSD; only higher Gf subjects who were rested showed a benefit in session 2. This work suggests that investigating premorbid individual differences may clarify our understanding of task-specific resilience during sleep deprivation.
Acknowledgements: Research supported by NIH grant CA167691 and CDMRP grant W81XWH-20-1-0442.

Kurinec, C., Whitney, P., Hinson, J., Satterfield, B., Honn, K., & Van Dongen, H. Unitization improves memory for associations during sleep deprivation. *Sleep*, 2022; 45 (Supplement 1): A48, published. Acknowledgement of federal support: yes.

0106

UNITIZATION IMPROVES MEMORY FOR ASSOCIATIONS DURING SLEEP DEPRIVATION

Courtney Kurinec[1], Paul Whitney[1], John Hinson[1], Brieann Satterfield[1], Kimberly Honn[1], Hans Van Dongen[1]
Washington State University [1]

Introduction: Total sleep deprivation (TSD) impairs binding, i.e., the ability to form new associations. Unitization – when separate memory items are learned as a single unit (e.g., combining two words into a novel compound word) – reduces the need for binding. Unitization mitigates impaired memory for associations in amnesiacs, but whether it offsets binding problems from TSD is unknown.

Methods: N=23 healthy adults (ages 19-35, 8 women) participated in an ongoing, double-blind, 4-day/3-night in-laboratory study with a 10h baseline sleep opportunity, 38h TSD, and a 10h recovery sleep opportunity. During TSD, participants were randomized to four administrations of caffeine (200mg), modafinil (alternating between 200mg and 0mg), or placebo at 4h intervals beginning at 01:00. They completed a unitization task at 14:45 on day 2 (baseline, session 1), day 3 (TSD, session 2), and day 4 (recovery, session 3). The task began with a study phase where participants studied 60 pairs of words that were presented individually (e.g., "penny" and "tower") or as new, unitized words (e.g., "pennytower") (50% each). Afterward, in the test phase, participants indicated whether 60 presented pairs of individual words were old (presented together at study) or new (recombined into new pairs) (50% each).

Results: Repeated-measures ANOVA revealed significant effects of study pair type (individual or unitized), session (1–3), and their interaction ($p<0.05$). Performance did not differ by pair type in session 1 ($p=0.46$), and performance for pairs of individual words did not change across sessions ($p=0.34$). However, performance on unitized word pairs improved across sessions ($p=0.003$), and unitized word pairs were recognized better than individual word pairs in sessions 2 and 3 ($p<0.05$).

Conclusion: Across sessions, participants benefitted from practice on unitized word pairs, such that performance improved even during TSD. Although potentially partly attributable to drug condition (to which investigators are still blinded), no such practice effect was seen for word pairs studied individually. Whether this dissociation implies that unitization bypasses the need for binding and thus lessens the impact of TSD requires further investigation. Regardless, unitization may mitigate performance impairment from sleep loss in settings that require forming novel associations, such as eyewitness identifications.

Support (If Any): USAMRDC W81XWH-18-1-0100 and CDMRP W81XWH-20-1-0442.

Moslener, E., & Honn, K. Performance on a computerized threat elimination task in an animated environment during total sleep deprivation. *Sleep*, 2022, 45 (Supplement 1): A53, published. Acknowledgement of federal support: yes.

0118

PERFORMANCE ON A COMPUTERIZED THREAT ELIMINATION TASK IN AN ANIMATED ENVIRONMENT DURING TOTAL SLEEP DEPRIVATION

Emily Moslener[1], *Kimberly Honn*[1]

Sleep and Performance Research Center and Elson S. Floyd College of Medicine, Washington State University, Spokane, WA [1]

Introduction: Military and law enforcement operators must make split-second decisions on whether to shoot during confrontations. Quick responses are crucial when force is necessary, but accurate decision-making is also imperative. Often, decisions are made while fatigued, which could impair speed and/or accuracy. Furthermore, the reliability of background information may impact performance. We investigated performance on a computerized shooting task during a total sleep deprivation (TSD) study.

Methods: N=86 healthy adults (39 males, age 21-38) completed a 4-day/3-night in-laboratory study, randomly assigned to a TSD (n=56) or control (n=28) condition. A custom task was administered after 32h or 8h of wakefulness (TSD and control groups). Participants were to shoot enemy robots (press spacebar) and not shoot friendly robots (no response) within 500ms of each robot being revealed inside shipping crates (1-5s inter-trial-interval). The task introduction described which crates would contain enemies, but the intel's accuracy varied across four phases: 100% (20 trials), 80% (120 trials), and 20% (40 trials), then irrelevant in a new environment (60 trials). Reaction time (RT) and accuracy (hits and false alarms (FAs)) were analyzed using 2x4 mixed-effects ANOVAs to determine the effects of condition, phase, and their interaction.

Results: There was a significant effect of phase on RT ($p<0.001$); in both conditions, participants reacted faster in phase 1 than all other phases. However, there was no effect of condition ($p=0.20$) or phase-condition interaction ($p=0.080$) on RT. There were significant effects of condition on hits ($p<0.001$) and FAs ($p=0.004$); TSD had fewer hits and more FAs than the control group. There was an effect of phase on hits ($p=0.045$), with fewer hits in phase 1, and a condition-phase interaction ($p=0.026$) showing that the TSD group experienced less improvement in hits. For FAs, there was no effect of phase ($p=0.86$) or phase-condition interaction ($p=0.86$).

Conclusion: The results suggest a speed/accuracy tradeoff during TSD, where relative to the control group, RTs remained equivalent, but accuracy was worse. In both groups, the RT slowing from phase 1 to subsequent phases, suggests that participants initially used the intel to facilitate quicker decision-making, but disregarded it once it was not completely reliable.

Support (If Any): CDMRP grants W81XWH-16-1-0319 and W81XWH-20-1-0442

Muck, R., Hudson, A., Honn, K., & Van Dongen, H. Is the timing of the endogenous circadian rhythm of neurobehavioral functioning inherently task-dependent? *Sleep*, 2022, 45 (Supplement 1): A99, published. Acknowledgement of federal support: yes.

0217

IS THE TIMING OF THE ENDOGENOUS CIRCADIAN RHYTHM OF NEUROBEHAVIORAL FUNCTIONING INHERENTLY TASK-DEPENDENT?

Rachael Muck[1], Amanda Hudson[1], Kimberly Honn[1], Hans Van Dongen[1]
Washington State University [1]

Introduction: Changes in waking neurobehavioral functioning (NF) over time are governed by homeostatic and circadian processes. It has been reported that peak circadian timing varies inherently between tasks, such that the optimal timing for NF would be task-dependent. Here we investigated this idea with a simulated shift work study protocol followed by a 24h constant routine (CR) protocol to experimentally and statistically separate the circadian from the homeostatic process.

Methods: N=13 healthy adults (ages 25.5±3.2y; 9 men) completed a 7-day/6-night in-laboratory study. They were randomized to a 3-day simulated day shift condition (n=7) with nighttime sleep (22:00–06:00) or a 3-day simulated night shift condition (n=6) with daytime sleep (10:00–18:00). They then underwent a 24h CR protocol, during which they stayed awake under constant behavioral and environmental conditions and blood was collected at 1–3h intervals for the assessment of dim light melatonin onset (DLMO). During scheduled wakefulness, subjects completed three functionally distinct NF tasks at ~2h intervals: the Karolinska Sleepiness Scale (KSS), Digit Symbol Substitution Test (DSST), and Psychomotor Vigilance Test (PVT). Data from these tasks taken during the CR protocol were analyzed with non-linear mixed-effects regression to separate endogenous circadian effects from the homeostatic process.

Results: Following simulated night shift, compared to simulated day shift, on average there was a modest, 1.4h (±0.8h SE) delay in DLMO ($F_{1,11}=3.68$, $p=0.082$). As such, the simulated night shift condition produced a 10.6h shift in alignment of the homeostatic process relative to the circadian process. Regardless of prior shift condition, the peak of the circadian rhythm effect on NF occurred post-DLMO by 16.8h (±1.0h) for KSS, 15.9h (±1.4h) for DSST, and 18.6h (±1.0h) for PVT, which was not significantly different ($F_{2,9}=1.55$, $p=0.26$).

Conclusion: As proof of principle, we studied three distinct NF assays, and found only small, non-significant differences between them in the timing of underlying circadian rhythmicity. While a larger sample could have yielded statistical significance in our comparison of circadian peak times, the small magnitude of the observed difference does not support the idea of inherent task-dependent differences in the timing of the endogenous circadian rhythm's influence on NF.

Support (If Any): CDMRP W81XWH-16-1-0319 and W81XWH-20-1-0442

Scott, J., Muck, R., Van Dongen, H., & Honn, K. Social desirability mediates self-reported sleepiness during a laboratory total sleep deprivation study. *Sleep*, 2022, 45 (Supplement 1): A131, published. Acknowledgement of federal support: yes.

0291

SOCIAL DESIRABILITY MEDIATES SELF-REPORTED SLEEPINESS DURING A LABORATORY TOTAL SLEEP DEPRIVATION STUDY

Jonah Scott[1], Rachael Muck[2], Hans Van Dongen[2], Kimberly Honn[2]
Washington State University Spokane [1] Washington State Unviersity Spokane [2]

Introduction: Total sleep deprivation (TSD) increases sleepiness and impairs vigilant attention. There are large individual differences in vulnerability to sleep loss, but individuals' self-ratings of sleepiness often do not align with their objective performance impairment. Here we investigated whether the trait of social desirability – the desire to conform to social standards – plays a role.

Methods: N=39 healthy adults (ages 27.6±4.6y; 22 men) completed a 3-night/4-day in-laboratory study with 10h baseline and recovery sleep opportunities (22:00–08:00) preceding and following a 38h period of TSD. Every 2–4h during TSD, subjects completed the Karolinska Sleepiness Scale (KSS) and a 10min Psychomotor Vigilance Test (PVT) to assess subjective sleepiness and vigilant attention, respectively. Throughout the study, subjects were behaviorally monitored by the researchers. Prior to the study, subjects completed the Marlow-Crowne Social Desirability (MCSD) scale. Based on standard criteria, subjects were categorized post hoc into average (n=13) and high (n=26) social desirability groups (no subjects in the sample scored low on social desirability). Self-reported sleepiness scored on the KSS and lapses (reaction times ≥500ms) on the PVT were analyzed using mixed-effects ANOVA with fixed effects for time awake and MCSD group and their interaction.

Results: As expected, there was a main effect of time awake for KSS score ($F[12,441]=31.48$, $p<0.001$) and PVT lapses ($F[12,441]=16.27$, $p<0.001$), with sleepiness and lapses increasing during TSD. We found a main effect of MCSD group for KSS score ($F[1,441]=4.56$, $p=0.033$), with the high MCSD group reporting lower levels of sleepiness than the average MCSD group. However, there was no effect of MCSD group for PVT lapses ($p=0.93$) and no time awake by MCSD interaction for either KSS ($p=0.86$) or PVT ($p=0.99$).

Conclusion: Subjects high in social desirability reported less sleepiness during TSD than those with average social desirability yet their objective performance was equally degraded. This finding has implications for fatigue risk management because individuals with high social desirability may underreport their sleepiness. This may undermine the reliability of self-report assessments of sleepiness and ability to work safely. [1] Whether there is bias in self-reported sleepiness for individuals low in social desirability as well remains to be investigated.

Support (If Any): Support: ONR N00014-13-1-0302 and PRMRP W81XWH-20-1-0442