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TITLE: Sleep Deprivation Effects on Cognitive Flexibility in Dynamic Decision-Making Environments

PRINCIPAL INVESTIGATOR: Hans P.A. Van Dongen, PhD

CONTRACTING ORGANIZATION: Washington State University
Pullman, WA 99164

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

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**6. AUTHOR(S)**
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**14. ABSTRACT**
Sleep loss, which is common in military operations, causes significant deficits in situational awareness and decision making. We showed that these critical performance deficits are caused by changes in attentional control in fast-paced, dynamically changing circumstances. There is currently no effective method to protect against these impairments in operational performance. In this project, we provide a foundation for the development of a training program that will address this issue by improving cognitive flexibility. In a laboratory-based study currently underway, healthy young adults are assigned to a sleep deprivation condition or to a control condition. The subjects are tested on performance tasks, specifically developed for this study in year 1 of the project, while well-rested and after 38 hours of sleep deprivation. A subset of the subjects assigned to the sleep deprivation condition participate in cognitive flexibility training. Our objective is to show that the cognitive flexibility training will help people to recover performance more quickly following unexpected changes of circumstances. By developing this novel method to increase resilience against operational performance impairment, our project will help to improve the safety and success of US military missions around the globe. The research will also benefit the millions of Americans who are frequently deprived of sleep due to medical conditions and/or professional demands.

**15. SUBJECT TERMS**
sleep deprivation, 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** |
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# 1. INTRODUCTION

Sleep loss, which is common in military operations, causes significant deficits in situational awareness and decision making. These critical performance deficits are caused by changes in attentional control in fast-paced, dynamically changing circumstances. There is currently no effective method to protect against these impairments in operational performance. In this research project, we seek to provide a foundation for the development of a training program that will address this issue by improving cognitive flexibility. In a laboratory-based study, healthy young adults are assigned to a sleep deprivation condition or to a control condition. The subjects are tested on performance tasks specifically developed for this study, while well-rested and after 38 hours of sleep deprivation (or equivalent well-rested control). A subset of the subjects assigned to the sleep deprivation condition participate in cognitive flexibility training. The objective is to show that the cognitive flexibility training will help to recover performance more quickly following unexpected changes of circumstances. By developing this novel method to increase resilience against operational performance impairment, this research project will help to improve the safety and success of US military missions around the globe. The research will also benefit the millions of Americans who are frequently deprived of sleep due to sleep disorders, other medical conditions, and/or professional demands.

## 2. KEYWORDS

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

## 3. ACCOMPLISHMENTS

**What were the major goals of the project?**

| **Specific Aim 1:** Demonstrate dissociable effects of sleep loss on vigilant attention and dynamic attentional control and isolate their influences in operationally relevant performance. | **Timeline** | **Completed** |
|---|---|---|
| **Study Preparations** | Months | |
| Milestone(s) Achieved: Procedures documented and IRB/HRPO approvals obtained | 1-3 | 10 Aug 2016 |
| **Data Collection** | | |
| Milestone(s) Achieved: Aim 1 data collection completed from 90 subjects (60 in a sleep deprivation condition and 30 in a control condition) | 7-30 | 17% completed |
| **Data Analysis** | | |
| Milestone(s) Achieved: Aim 1 analyses completed | 31-33 | n/a |
| **Specific Aim 2:** Show that effects of sleep loss on the use of proactive and reactive control are responsible for failures of situational awareness and risky decision errors. | | |
| **Data Collection** | | |
| Milestone(s) Achieved: Aim 2 data collection completed from 90 subjects (60 in a sleep deprivation condition and 30 in a control condition) | 7-30 | 17% completed |
| **Data Analysis** | | |
| Milestone(s) Achieved: Aim 2 analyses completed | 31-33 | n/a |
| **Specific Aim 3:** Develop cognitive flexibility training as a method to protect against sleep loss-induced failures of situational awareness and risky decision errors. | | |
| **Data Collection** | | |
| Milestone(s) Achieved: Aim 3 data collection completed from 90 subjects (60 in a sleep deprivation condition and 30 in a control condition) | 7-30 | 17% completed |
| **Data Analysis** | | |
| Milestone(s) Achieved: Aim 3 analyses completed | 31-33 | 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 1, the major activities to be completed to achieve the goal milestones were:*

- Ethical review of the study procedures by the Washington State University IRB and the DoD's HRPO – completed.
- Development of standard operating procedures for participant screening and enrollment (Aims 1–3) – completed.
- Development of cognitive tests for dissociation of the effects of sleep loss on vigilant attention and dynamic attentional control and isolate their influences in operationally relevant performance (Aim 1) – completed.
- Development of cognitive tests to show that the effects of sleep loss on the use of proactive and reactive control are responsible for failures of situational awareness and risky decision errors (Aim 2) – completed.
- Development of a cognitive flexibility training module (Aim 3) – completed.
- Development of an operationally relevant cognitive flexibility performance testing platform (Aim 3) – completed.
- Development and implementation of a detailed study protocol and standard operating procedures pertaining to cognitive task administration for the laboratory study (Aims 1–3) – completed.
- Development and implementation of all other laboratory study procedures, including standardized laboratory environment (fixed light levels, fixed ambient temperature, constant supervision of subjects), streamlined logistics (24/7 research assistant schedules, standardized meals for subjects, etc.), polysomnographic recordings, skin conductance recordings (Aims 1–3) – completed.
- Recruiting and screening healthy subjects for the laboratory study (Aims 1–3) – multi-year effort (months 7–30), in progress and on target.
- Studying subjects in the laboratory (Aims 1–3) – multi-year effort (months 7–30), in progress and on target (17% completed).

*Summary of the laboratory study protocol:* Carefully screened, healthy young adults are randomized to a 38-hour sleep deprivation condition (n=60) or well-rested control condition (n=30). Subjects are in the laboratory for four days / three nights continuously,

under constant observation and physiological monitoring. In the sleep deprivation condition, subjects have one night with 10 hours time in bed for baseline sleep, then undergo 38 hours of total sleep deprivation (equivalent to missing one night of sleep), and then are given one recovery night with 10 hours time in bed for sleep. Those in the control condition have 10 hours in bed for sleep on all three nights. Subjects are tested on a range of cognitive performance tasks at baseline and after sleep deprivation (or well-rested control). Half the subjects in the sleep deprivation condition receive training on a cognitive flexibility task during the study. Near the end of the sleep deprivation period (or well-rested control), all subjects are tested on an operationally relevant task requiring situational awareness and cognitive flexibility. The cognitive tests and physiological measures obtained during the study serve to demonstrate dissociable effects of sleep loss on vigilant attention and dynamic attentional control and isolate their influences in operationally relevant performance; show that effects of sleep loss on the use of proactive and reactive control are responsible for failures of situational awareness and risky decision errors; and investigate cognitive flexibility training as a method to protect against sleep loss-induced failures of situational awareness and risky decision errors.

*Stated goals not met:* none.

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

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

- A Ph.D. student in the Neuroscience program at Washington State University, Darian Sidebottom, is involved in dissertation research integrated with the project. This includes training in the management and processes of biosamples for subject screening and (ultimately) biomarker assessment; recording and scoring of sleep (polysomnography); recording and processing of galvanic skin conductance; 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 the PI and Co-PIs of the project, and training and experience is gained on a daily basis and in considerable depth. During Year 1, the graduate student presented her work at a national conference on sleep science.

- A M.S. student in the Experimental Psychology program (with Quantitative Concentration) at Washington State University, Samantha Riedy, is involved with the project as a sleep specialist who is already Board-certified (i.e., Registered Polysomnographic Technologist). With regard to education and training, the project offers unique opportunities to study the cognitive, psychometric, and statistical characteristics of performance outcomes on the various cognitive tests. Shortly after the end of Year 1 of the project, the student earner her M.S. degree on a thesis involving a detailed study of metrics of sustained attention. She is now embarking on a Ph.D. dissertation project that will incorporate flexible attentional control, for which the project will again provide a unique training opportunity. During Year 1, the graduate student presented her work at a national conference on sleep science and an international conference on fatigue risk management.
- Two post-baccalaureate research assistants, Regan Permito and Elizabeth Lewis, are involved in the project during all stages of subject recruitment and screening and laboratory investigation and logistics. They will also each be assigned a subset of the data collected in the study for independent processing and analysis under the supervision of the PI and Co-PIs. We offer this post-baccalaureate training opportunity because the experience gained is widely considered of significant benefit for applications to graduate and medical school – the vast majority of our postbaccalaureate trainees go on (after a year or two) to enroll in Ph.D. and M.D. programs across the country. The two post-baccalaureate research assistants currently involved in the project will be presenting their work at a national conference in 2018.
- More than a dozen undergraduate students are involved in the project, providing around-the-clock staffing and constant behavioral monitoring during the 24/7 laboratory experimentation of the project. Records show that the experience gained in the laboratory helps these students significantly with their applications for graduate and medical school (or other endeavors they choose to pursue).

**How were the results disseminated to communities of interest?**

Nothing to Report.

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

During Year 2, we will continue subject recruitment and screening and studying subjects in the laboratory sleep deprivation experiment per the timeline outlined in the table on page 6. Our goal will be to have completed 60 subjects by the end of Year 2.

We expect that some of the data collected during the study will be amenable for preliminary analyses, which will be used in training opportunities for graduate students and post-baccalaureate students (see above) and presented at national conferences.

## 4. IMPACT

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

We developed a novel, operationally relevant performance task that allows us to differentiate proactive from reactive attentional control strategies in violent encounter decision making. The task involves simulated, fast-paced encounters with robots that may be either hostile or friendly based on observable contingencies that change dynamically. This is the first cognitive testing platform to become available for the systematic, theoretically grounded investigation of the effects of sleep deprivation on cognitive flexibility with direct relevance to military operations. During the project, the task is used to help assess the effectiveness of cognitive flexibility training to confer resilience to the adverse effects of sleep deprivation. Following completion of the current project, the task will also be made available to the military and civilian research communities.

**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?**

One of the pervasive – but poorly understood – effects of sleep deprivation on society is its disastrous impact on decision making, in ways that cannot be explained by well-known effects of sleep loss such as attentional lapsing. Well-known examples include the Space Shuttle Challenger accident and the nuclear meltdown at Chernobyl; other examples abound. This project will, for the first time, expose the basic mechanisms that

underlie this phenomenon; *and it seeks to provide a cognitive/behavioral countermeasure that can be readily implemented* both in the military and in the civilian sector.

## 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

Due to typical seasonal fluctuations, we are currently a few (less than 5%) subjects behind schedule in terms of subject recruitment and screening. Our study schedule is such that we will again be at or above target recruitment levels by the middle of Year 2. Although we are early in the project and no intervention is needed at this time, we have nonetheless intensified our advertising efforts to compensate for this minor fluctuation in subject recruitment even sooner.

### Changes that had a significant impact on expenditures

Nothing to Report.

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

A minor adverse event occurred on 16 Jun 2017, involving a prospective subject fainting and shaking following a blood draw during screening. The event was unexpected but not clinically significant, and resolved without need for follow-up intervention. The event was reported to Washington State University's IRB, which after review approved the adverse event report on 24 Jul 2017. The event was also reported to the DoD's HRPO, which acknowledged concurrence with the IRB's determination on 1 Aug 2017. *HRPO stated that the event requires no further action*.

**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

### Journal publications

Ratcliff R, Van Dongen HPA. The effects of sleep deprivation on item and associative recognition memory. Journal of Experimental Psychology: Learning, Memory, and Cognition, accepted. Acknowledgement of federal support: yes.

Walsh MM, Gunzelmann G, Van Dongen HPA. Computational cognitive modeling of the temporal dynamics of fatigue from sleep loss. Psychonomic Bulletin & Review, accepted. Acknowledgement of federal support: yes.

*Copies of the published versions of these articles will be included in the Appendix of next year's annual report.*

### Books or other non-periodical, one-time publications

*Ph.D. dissertations:*

Satterfield BC. Genetic markers of inter-individual and task-dependent differences in neurobehavioral impairment during total sleep deprivation. Ph.D. dissertation, 2017, Washington State University, accepted. Acknowledgement of federal support: yes.

Skornyakov S. Sleep, autonomic nervous system, and neurobehavioral outcomes. Ph.D. dissertation, 2017, Washington State University, accepted. Acknowledgement of federal support: yes.

*Conference abstracts:*

Satterfield BC, Wisor JP, Schmidt MA, Van Dongen H. DAT1 genotype modulates the time-on-task effect on the PVT during total sleep deprivation. Sleep 40 (Abstract Suppl.): A1-A2. Acknowledgement of federal support: yes. See Appendix.

**Other publications, conference papers, and presentations**

*Invited lectures:*

Van Dongen HPA. Sleep deprivation: Effects on health, performance, and safety. Invited lecture at the 2017 Northwest Safety & Health Summit; Spokane, Washington, May 2017.

Van Dongen HPA. Impairments in cognitive performance and emotion regulation due to sleep deprivation. Invited symposium presentation at the SLEEP 2017 conference; Boston, Massachusetts, June 2017.

*Oral presentations at conferences:*

Van Dongen HPA. Toward a common metric for risk assessment across diverse factors in fatigue risk management systems: Quantifying human performance in terms of signal-to-noise ratio. Oral presentation at the 10th International Conference on Managing Fatigue; San Diego, California, March 2017.

Van Dongen HPA. Impaired cognitive flexibility due to sleep deprivation predicts degraded deadly force decision-making in high-fidelity law enforcement simulations. Oral presentation at the SLEEP 2017 conference; Boston, Massachusetts, June 2017.

**Website(s) or other Internet site(s)**

Nothing to Report.

**Technologies or techniques**

We developed a novel, operationally relevant performance task for Windows-based computer platforms, which allows us to differentiate proactive from reactive attentional

control strategies in violent encounter decision making. The task involves simulated, fast-paced encounters with robots that may be either hostile or friendly based on observable contingencies that change dynamically. This is the first cognitive testing platform to become available for the systematic, theoretically grounded investigation of the effects of sleep deprivation on cognitive flexibility with direct relevance to military operations. During the project, the task is used to help assess the effectiveness of cognitive flexibility training to confer resilience to the adverse effects of sleep deprivation. Following completion of the current project, the task will be made available to the military and civilian research communities at no cost.

**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: | *3* |
| Contribution to Project: | *Dr. Honn oversaw the laboratory experimentation and the development of the operationally relevant cognitive flexibility task.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Matthew E. Layton, M.D., Ph.D.* |
| Project Role: | *Co-PI* |
| Researcher Identifier: | *ORCID ID: 0000-0002-3287-9203* |
| Nearest person month worked: | *2* |
| Contribution to Project: | *Dr. Layton served as physician of record for the study and oversaw subject health and well-being.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Paul Whitney, Ph.D.* |
| Project Role: | *Co-PI* |
| Researcher Identifier: | *ORCID ID: 0000-0003-1973-5261* |
| Nearest person month worked: | *2* |
| Contribution to Project: | *Dr. Whitney contributed key expertise on the measurement of cognitive flexibility and developed the cognitive flexibility training intervention.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *John M. Hinson, Ph.D.* |
| Project Role: | *Co-PI* |
| Researcher Identifier: | *ORCID ID: 0000-0002-5012-5974* |
| Nearest person month worked: | *2* |
| Contribution to Project: | *Dr. Hinson contributed critical expertise on decision making, led the development of performance task, and implemented skin conductance procedures.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Devon A. Grant, Ph.D.* |
| Project Role: | *Postdoctoral Researcher* |
| Researcher Identifier: | *Washington State University ID: 10064965* |
| Nearest person month worked: | *1* |
| Contribution to Project: | *Dr. Grant helped develop study procedures, standing operating procedures, and recruitment and screening protocols.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Naghmana Sherazi, M.A.* |
| Project Role: | *Study Coordinator* |
| Researcher Identifier: | *Washington State University ID: 11506109* |
| Nearest person month worked: | *4* |
| Contribution to Project: | *Ms. Sherazi coordinated staffing and logistics for the study.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Brieann C. Satterfield* |
| Project Role: | *Ph.D. Student* |
| Researcher Identifier: | *Washington State University ID: 10863150* |
| Nearest person month worked: | *1* |
| Contribution to Project: | *Ms. Satterfield managed biosample collection for subject screening. In addition, she studied decision making tasks as part of her dissertation research. Ms. Satterfield earned her Ph.D. degree in April 2017.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Elena Skornyakov, DPT* |
| Project Role: | *Ph.D. Student* |
| Researcher Identifier: | *Washington State University ID: 11385983* |
| Nearest person month worked: | *1* |
| Contribution to Project: | *Ms. Skornyakov developed procedures for heart rate variability recording and processing, used in the study, as part of her dissertation research. Ms. Skornyakov earned her Ph.D. degree in July 2017.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Darian Sidebottom* |
| Project Role: | *Ph.D. Student* |
| Researcher Identifier: | *Washington State University ID: 11357866* |
| Nearest person month worked: | *4* |
| Contribution to Project: | *Ms. Sidebottom programmed cognitive performance tasks for the study. She also took over management of biosamples for screening sessions from Ms. Satterfield after the latter's graduation, and contributed to the laboratory experimentation.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Amy Sparrow, M.S.* |
| Project Role: | *Ph.D. Student* |
| Researcher Identifier: | *Washington State University ID: 10638159* |
| Nearest person month worked: | *1* |
| Contribution to Project: | *Ms. Sparrow monitored subjects in the laboratory, administered performance tasks, and performed physiological recordings.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Samantha Riedy, RPSGT* |
| Project Role: | *Sleep Technologist* |
| Researcher Identifier: | *Washington State University ID: 11365976* |
| Nearest person month worked: | *3* |
| Contribution to Project: | *Ms. Riedy served as the designated sleep technologist for the study, overseeing recording and scoring of sleep.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Regan Permito* |
| Project Role: | *Postbaccalaureate Research Assistant* |
| Researcher Identifier: | *Washington State University ID: 11498976* |
| Nearest person month worked: | *2* |
| Contribution to Project: | *Ms. Permito conducted screening sessions for the study and performed laboratory set-up for the experiment.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Elizabeth G. Lewis* |
| Project Role: | *Postbaccalaureate Research Assistant* |
| Researcher Identifier: | *Washington State University ID: 11499707* |
| Nearest person month worked: | *1* |
| Contribution to Project: | *Ms. Lewis conducted screening sessions for the study and performed laboratory set-up for the experiment.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Elizabeth Dotson, M.S.* |
| Project Role: | *Research Intern* |
| Researcher Identifier: | *Washington State University ID: 11094140* |
| Nearest person month worked: | *1* |
| Contribution to Project: | *Ms. Dotson monitored subjects in the laboratory, administered performance tasks, and performed physiological recordings.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Roxanne Bataller* |
| Project Role: | *Undergraduate Research Assistant* |
| Researcher Identifier: | *Washington State University ID: 11474968* |
| Nearest person month worked: | *1* |
| Contribution to Project: | *Ms. Bataller monitored subjects in the laboratory, administered performance tasks, and performed physiological recordings.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *John D. Beattie* |
| Project Role: | *Undergraduate Research Assistant* |
| Researcher Identifier: | *Washington State University ID: 11448523* |
| Nearest person month worked: | *1* |
| Contribution to Project: | *Mr. Beattie monitored subjects in the laboratory, administered performance tasks, and performed physiological recordings.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Ariel Bermudez* |
| Project Role: | *Undergraduate Research Assistant* |
| Researcher Identifier: | *Washington State University ID: 11561043* |
| Nearest person month worked: | *1* |
| Contribution to Project: | *Ms. Bermudez monitored subjects in the laboratory, administered performance tasks, and performed physiological recordings.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Mitchell T. Davey* |
| Project Role: | *Undergraduate Research Assistant* |
| Researcher Identifier: | *Washington State University ID: 11383297* |
| Nearest person month worked: | *1* |
| Contribution to Project: | *Mr. Davey monitored subjects in the laboratory, administered performance tasks, and performed physiological recordings.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Karly Dougherty* |
| Project Role: | *Undergraduate Research Assistant* |
| Researcher Identifier: | *Washington State University ID: 11594060* |
| Nearest person month worked: | *1* |
| Contribution to Project: | *Ms. Dougherty monitored subjects in the laboratory, administered performance tasks, and performed physiological recordings.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Nicholas Ensroth* |
| Project Role: | *Undergraduate Research Assistant* |
| Researcher Identifier: | *Washington State University ID: 11594012* |
| Nearest person month worked: | *1* |
| Contribution to Project: | *Mr. Ensroth monitored subjects in the laboratory, administered performance tasks, and performed physiological recordings.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Derrik Gratz* |
| Project Role: | *Undergraduate Research Assistant* |
| Researcher Identifier: | *Washington State University ID: 11599911* |
| Nearest person month worked: | *1* |
| Contribution to Project: | *Mr. Gratz monitored subjects in the laboratory, administered performance tasks, and performed physiological recordings.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Anna Hubbell* |
| Project Role: | *Undergraduate Research Assistant* |
| Researcher Identifier: | *Washington State University ID: 11599385* |
| Nearest person month worked: | *1* |
| Contribution to Project: | *Ms. Hubbell monitored subjects in the laboratory, administered performance tasks, and performed physiological recordings.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *S. McKenzie Kwate* |
| Project Role: | *Undergraduate Research Assistant* |
| Researcher Identifier: | *Washington State University ID: 11459552* |
| Nearest person month worked: | *1* |
| Contribution to Project: | *Ms. Kwate monitored subjects in the laboratory, administered performance tasks, and performed physiological recordings.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Riley Meister* |
| Project Role: | *Undergraduate Research Assistant* |
| Researcher Identifier: | *Washington State University ID: 11600345* |
| Nearest person month worked: | *1* |
| Contribution to Project: | *Ms. Meister monitored subjects in the laboratory, administered performance tasks, and performed physiological recordings.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Amelia Mills* |
| Project Role: | *Undergraduate Research Assistant* |
| Researcher Identifier: | *Washington State University ID: 11524215* |
| Nearest person month worked: | *1* |
| Contribution to Project: | *Ms. Mills monitored subjects in the laboratory, administered performance tasks, and performed physiological recordings.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Samia Quidwai* |
| Project Role: | *Undergraduate Research Assistant* |
| Researcher Identifier: | *Washington State University ID: 11470835* |
| Nearest person month worked: | *1* |
| Contribution to Project: | *Ms. Quidwai monitored subjects in the laboratory, administered performance tasks, and performed physiological recordings.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Alena Rael* |
| Project Role: | *Undergraduate Research Assistant* |
| Researcher Identifier: | *Washington State University ID: 11561215* |
| Nearest person month worked: | *1* |
| Contribution to Project: | *Ms. Rael monitored subjects in the laboratory, administered performance tasks, and performed physiological recordings.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Erika Santacruz* |
| Project Role: | *Undergraduate Research Assistant* |
| Researcher Identifier: | *Washington State University ID: 11437499* |
| Nearest person month worked: | *1* |
| Contribution to Project: | *Ms. Santacruz monitored subjects in the laboratory, administered performance tasks, and performed physiological recordings.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Amanda Sursely* |
| Project Role: | *Undergraduate Research Assistant* |
| Researcher Identifier: | *Washington State University ID: 11413082* |
| Nearest person month worked: | *1* |
| Contribution to Project: | *Ms. Sursely monitored subjects in the laboratory, administered performance tasks, and performed physiological recordings.* |
| Funding Support: | |

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|---|---|
| Name: | *Hailey Swearingen* |
| Project Role: | *Undergraduate Research Assistant* |
| Researcher Identifier: | *Washington State University ID: 11599921* |
| Nearest person month worked: | *1* |
| Contribution to Project: | *Ms. Swearingen monitored subjects in the laboratory, administered performance tasks, and performed physiological recordings.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Nathanial Swearingen* |
| Project Role: | *Undergraduate Research Assistant* |
| Researcher Identifier: | *Washington State University ID: 11560892* |
| Nearest person month worked: | *1* |
| Contribution to Project: | *Mr. Swearingen monitored subjects in the laboratory, administered performance tasks, and performed physiological recordings.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Christopher Thomas* |
| Project Role: | *Undergraduate Research Assistant* |
| Researcher Identifier: | *Washington State University ID: 115399331* |
| Nearest person month worked: | *1* |
| Contribution to Project: | *Mr. Thomas monitored subjects in the laboratory, administered performance tasks, and performed physiological recordings.* |
| Funding Support: | |

| | |
|---|---|
| Name: | *Brian T. Ward* |
| Project Role: | *Undergraduate Research Assistant* |
| Researcher Identifier: | *Washington State University ID: 11593977* |
| Nearest person month worked: | *1* |
| Contribution to Project: | *Mr. Ward monitored subjects in the laboratory, administered performance tasks, and performed physiological recordings.* |
| Funding Support: | |

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|---|---|
| Name: | *Mackenzie Welsh* |
| Project Role: | *Undergraduate Research Assistant* |
| Researcher Identifier: | *Washington State University ID: 11561106* |
| Nearest person month worked: | *1* |
| Contribution to Project: | *Ms. Welsh monitored subjects in the laboratory, administered performance tasks, and performed physiological recordings.* |
| Funding Support: | |

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|---|---|
| Name: | *Madelaine R. Wiersma* |
| Project Role: | *Undergraduate Research Assistant* |
| Researcher Identifier: | *Washington State University ID: 11499681* |
| Nearest person month worked: | *1* |
| Contribution to Project: | *Ms. Wiersma monitored subjects in the laboratory, administered performance tasks, and performed physiological recordings.* |
| 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

Nothing to Report.

# 9. APPENDIX

*Conference abstract:*

Satterfield BC, Wisor JP, Schmidt MA, Van Dongen H. DAT1 genotype modulates the time-on-task effect on the PVT during total sleep deprivation. Sleep 40 (Abstract Suppl.): A1-A2.

**DAT1 GENOTYPE MODULATES THE TIME-ON-TASK EFFECT ON THE PVT DURING TOTAL SLEEP DEPRIVATION**

*Satterfield BC, Wisor JP, Schmidt MA, Van Dongen H*
Sleep and Performance Research Center, Washington State University, Spokane, WA

**Introduction:** Previous research has shown that the magnitude of the time-on-task (TOT) effect, which is the increase in response variability across the duration of a demanding sustained performance task, is affected by a variable number tandem repeat (VNTR) polymorphism in the Dopamine Transporter SL6CA3 gene (DAT1). Sleep deprivation also induces response variability in such tasks, and amplifies the TOT effect, which suggests shared underlying mechanisms. To explore one possible shared mechanism, we investigated whether DAT1 genotype affects the interaction between the TOT effect and total sleep deprivation (TSD).

**Methods:** 82 healthy adults (27.0±4.7y; 43 females) participated in one of three laboratory studies. Following a baseline period, subjects underwent at least 38h of TSD. A 10-min psychomotor vigilance test (PVT) was administered 12 times throughout the 38h TSD period. For each test bout and each subject, response times were aggregated into 1-min bins. DAT1 was assayed from blood using PCR and visualized by gel electrophoresis. 79 subjects had the 9- or 10-repeat alleles of DAT1. Another 3 subjects had the rare 8- or 11-repeat variants; they were not used for analysis.

**Results:** Mixed-effects ANOVA, controlling for study, showed a significant interaction between 1-min bins and DAT1 genotype ($F_{9,87000}$=3.07, P=0.001). As observed previously, the TOT effect was reduced in subjects homozygous for the 10-repeat allele. There was also a significant interaction of 1-min bins, time awake, and DAT1 genotype ($F_{99,87000}$=1.35, P=0.011). Subjects homozygous for the 10-repeat allele showed less amplification of the TOT effect during TSD than subjects with the 9-repeat allele.

**Conclusion:** DAT1 genotype modulates the TOT effect on the PVT during TSD. DAT1 is preferentially expressed in the striatum, where genotype affects DAT1 expression and dopamine availability. This suggests a role for striatal dopamine in shaping the impact of TOT and sleep deprivation on performance as measured with the PVT.

**Support (If Any):** ONR grant N00014-13-1-0302, NIH grants R21CA167691 and R01HL105768, FAA grant DTFAAC-11-A-00003, CDMRP grant W81XWH-16-1-0319.