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Award Number: W81XWH-05-1-0099

TITLE: SLEEP AND PERFORMANCE RESEARCH CENTER

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REPORT DATE: May 2012

TYPE OF REPORT: Addendum

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

DISTRIBUTION STATEMENT: Approved for Public Release;
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REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
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1. REPORT DATE May 2012		2. REPORT TYPE Addendum		3. DATES COVERED 1 May 2011- 30 April 2012	
4. TITLE AND SUBTITLE SLEEP AND PERFORMANCE RESEARCH CENTER				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Gregory Belenky, MD				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Washington State University Spokane, WA 99202				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Medical Research and Materiel 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 The key deliverable in this award's statement of work to "Develop a new program at Washington State University- the Spokane Sleep Research Initiative to focus on the effects of sleep and sleep loss on human performance." As the Spokane Sleep Research Initiative grew, it was renamed the Sleep Performance Research Center (SPRC). Three major findings were published during the interval covered by this addendum (05/01/2011-04/30/2012). First the theory of local sleep was further developed. Second, the performance development caused by sleep loss can be predicted by mathematical models taking sleep/wake history and phase and inputs. Third the need for a restart break depends upon the placement of the work period with respect to the circadian rhythm. Additional studies were published by SPRC care factually during the same period concerned with the neurobiology of sleep, the behavioral consequences of sleep loss, and the use of mathematical models in fatigue risk management. During the interval covered by this addendum (05/01/2011-04/30/2012), the Sleep Performance Research Center 11 core faculty members have produced 94 publications					
15. SUBJECT TERMS- sleep, sleep loss, human performance					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			USAMRMC
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Introduction

The Sleep and Performance Research Center (SPRC) conducts human and animal studies in laboratory and field settings in support of basic and applied sleep research at Washington State University (WSU). The SPRC focuses on understanding the brain organization of sleep in humans and animals and on using this understanding to link sleep, by way of the underlying neurobiology, to key indicators of performance, be they physiological, behavioral or cognitive. The research contributes to sustaining human productivity, safety, health, and well-being and may contribute to the understanding of the neurobiology of consciousness.

The SPRC core faculty members are:

Gregory Belenky, M.D., Research Professor, VCAPP, WSU Spokane (SPRC Director)

Christopher Davis, Ph.D., Assistant Research Professor, WWAMI, WSU Spokane

Lois James, Ph.D., Assistant Research Professor, Criminal Justice and Criminology, WSU Spokane

Levente Kapás, M.D., Ph.D., Associate Professor, VCAPP, WWAMI, WSU Spokane

Ilia Karatsoreos, Ph.D., Assistant Professor, VCAPP, WSU Pullman

James Krueger, Ph.D., Regents Professor, VCAPP, WWAMI, WSU Spokane

Jaak Panksepp, Ph.D., Professor, VCAPP, WSU Pullman

David Rector, Ph.D., Professor, VCAPP, WSU Pullman (left WSU in 2011)

Éva Szentirmai, M.D., Ph.D., Assistant Professor, VCAPP, WWAMI, WSU Spokane

Hans Van Dongen, Ph.D., Research Professor, VCAPP, WSU Spokane (SPRC Assistant Director)

Bryan Vila, Ph.D., Professor, Criminal Justice and Criminology, WSU Spokane

Jonathan Wisor, Ph.D., Associate Professor, VCAPP, WWAMI, WSU Spokane

The current eleven SPRC core faculty members are all involved in sleep research and their productivity is evidenced by their collective publications and extramural funding. SPRC core faculty members are internationally renowned for their scientific contributions, which have led to paradigm shifts in science and policy changes at the state and national levels.

Program of Research

Field Studies in Humans

In a field study of serving police officers, Charles, et al. (2011) found that perceived shorter sleep duration and poorer sleep quality was associated with greater perceived stress.

In a retrospective study of the crash of Comair 5191, Pruchnicki, Wu, and Belenky (2010) found that mathematical modeling predicting performance based on reconstructed sleep/wake history indicated fatigue in the pilots and the air traffic controller at the time of the demonstrating the utility of such models in accident reconstruction.

In a study of railroad personnel, Raslear, Hursh, and Van Dongen (2011) found a negative correlation between mathematical models prediction of cognitive performance based on sleep/wake history and actual risk of accident, demonstrating the possible utility of such models in fatigue risk management.

Laboratory Studies in Humans

In a laboratory study, Ratcliff and Van Dongen (2011) applied the diffusion model to the analysis of the cognitive effects of sleep loss and found that this model had explanatory power in describing the effects of sleep loss on performance.

In a laboratory study, Van Dongen, Belenky, and Vila (2011) demonstrated the importance of circadian rhythm phase (time of day) in determining the efficacy of a recycling restart break. This lends support for the idea that in the first 24-48 hours of shiftwork it is the circadian rhythm in alertness rather than time awake that is the primary determinant of performance.

Integrated Laboratory and Field Studies in Humans

In a laboratory and operational field study, Van Dongen, Caldwell, and Caldwell (2011) found trait-like individual differences in resistance to performance degradation due to sleep loss suggesting the possible utility of selection of resistant individuals to staff critical operational positions.

Laboratory Studies in Animals

In a series of laboratory studies in animals, Davis et al. (2011) studied the effect of micro RNA on sleep, Gardi et al. (2011) described the regulation of homeostasis in hibernating bears by brain peptides, Jiang et al. (2011) described a mouse model of advanced sleep phase syndrome, Karatsoreos, et al. (2011) described the effect of disrupting the circadian clock on brain and body metabolism and behavior, Karatsoreos, et al. (2011) described the effect of androgens on the plasticity of the

suprachiasmatic nucleus, Moriarty et al. (2011) described the attenuation of the alerting effects of hypocretin by aging, Oonk, et al. (2011) experimented with two-trial, Y-maze performance as a behavioral assay for the effects of sleep loss on performance, Phillips et al. (2011) described the cortical evoked responses associated with awakening from sleep, Reynolds et al. (2011) assessed the effect of endogenous testosterone on cognitive performance during sleep loss, Schei and Rector (2011) studied cerebral vascular response during sleep and following sleep deprivation, Walker et al. (2011) developed conditioned lick behavior and a rat whisker twitch apparatus to assess the effects of local sleep on brain responsiveness, Winters et al. (2011) showed sleep loss affecting synaptic connectivity in mouse prefrontal cortex, Wisor et al. (2011) in a series of papers investigated inflammation, slow wave sleep homeostasis, local sleep regulatory substances and their interaction in sleep.

Reviews

Clinton et al. (2011) reviewed the biochemical regulation of sleep and associated biomarkers. Davis et al. (2011) reviewed the biological significance of delta wave power during sleep. Dawson et al. (2011) reviewed the usefulness of mathematical modeling in fatigue risk management in the operational environment. Garashchenko, Wisor, and Kilduff (2011) reviewed the role of sleep active brain cells in generating slow waves in the cortex. Gunzelman et al. (2011) in a review decomposed attention into its components parts to differentiate and correlate time on task and time awake. Jackson and Van Dongen (2011) reviewed the role of sleepiness in degrading cognitive performance. Karatsoreos in two reviews (2011) summarized what is known about stress and resistance to stress in the context of human performance. Krueger et al. (2011) in seven reviews covered what is known about sleep and host defense, cytokines in slow wave sleep, cytokines, sleep, and immune function, the theory of local use dependent sleep, the role of local sleep regulatory substances in initiating local and whole brain sleep, and immune function and sleep regulation. Belenky et al. (2011) discussed techniques and technologies for measuring sleep and performance in the operational environment. Schei and Rector (2011) reviewed the effect of local network activity on local hemodynamics in the cortex. Sengupta et al. (2011) reviewed the cytokine/adenosine hypothesis for how the brain translates past activity into present sleep. Van Dongen, Belenky, and Krueger reviewed the theory of local sleep in the context of a bottom-up perspective with sleep as an emergent property. Van Dongen, Belenky and Krueger reviewed the temporal dynamics (time on task) aspects on cognitive fatigue. Van Dongen and Kerkhoff (2011) edited a book that covered multiple areas of contemporary sleep research both animal and human as it relates to cognition. Finally, Zielinski and Krueger (2011) reviewed the literature on sleep and immunity.

Key Research Accomplishments

- The shorter and poorer quality sleep, the greater the perceived stress in police officers.
- Mathematical models predicting sleep loss and circadian rhythm phase related performance can be useful in accident reconstruction if sleep/wake history is known and circadian rhythm phase can be estimated.
- Mathematical models predicting sleep and circadian rhythm-related performance can predict accident risk in rail operations.
- Mathematical models based on the principles of diffusion can describe the dynamics of performance degradation in sleep loss.
- Circadian timing of work shifts in large measure determine the need for a restart break after multiple on-duty days
- Trait-like inter-individual variability in sensitivity to sleep loss can be detected in both laboratory and field studies.
- Multiple laboratory studies in animals are unraveling the neurobiology of sleep and sleep loss effects on performance.
- The theory of local sleep was further developed and is increasingly widely accepted.
- Multiple reviews of both human and animal studies of sleep and performance were published by the core faculty.

Reportable Outcomes

- Sleep loss effects on performance can be predicted by mathematical models taking sleep/wake history and circadian rhythm phase as inputs and are useful for prospective fatigue risk management and retrospective accident analysis.
- The need for a restart break in a given work rest schedule is dependent on the placement of the schedule with respect to circadian rhythm phase.
- The theory that sleep begins locally in one or more brain areas and spreads to involve the whole brain is gaining increasing acceptance in the scientific community.

Conclusions

Sleep, sleep loss, and performance are active areas of research with progress being made through field studies of humans, laboratory studies of humans and animals, field and laboratory studies of humans, and scholarly review of the existing scientific literature.

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