Fiscal Year:	FY 2016	**Task Last Updated:**	FY 07/20/2016
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Project Title:	Quantifying and Developing Countermeasures for the Effect of Fatigue-Related Stressors on Automation Use and Trust During Robotic Supervisory Control		
Division Name:	Human Research		
Program/Discipline:	NSBRI		
Program/Discipline--Element/Subdiscipline:	NSBRI--Human Factors and Performance Team		
Joint Agency Name:		**TechPort:**	Yes
Human Research Program Elements:	(1) **HFBP**:Human Factors & Behavioral Performance (IRP Rev H)		
Human Research Program Risks:	(1) **HSIA**:Risk of Adverse Outcomes Due to Inadequate Human Systems Integration Architecture		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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Zip Code:	77058	**Congressional District:**	22
Comments:			
Project Type:	Ground	**Solicitation / Funding Source:**	2014-15 HERO NNJ14ZSA001N-Crew Health (FLAGSHIP & NSBRI)
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No. of Post Docs:	0	**No. of PhD Degrees:**	0
No. of PhD Candidates:	0	**No. of Master' Degrees:**	0
No. of Master's Candidates:	1	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	0	**Monitoring Center:**	NSBRI
Contact Monitor:		**Contact Phone:**	
Contact Email:			
Flight Program:			
Flight Assignment:	NOTE: Element change to Human Factors & Behavioral Performance; previously Space Human Factors & Habitability (Ed., 1/19/17) NOTE: Period of performance changed to 6/1/2015-5/31/2017 per NSBRI (original period of performance was 5/31/15-5/30/17)--Ed., 6/25/15		
Key Personnel Changes/Previous PI:			
COI Name (Institution):	Billman, Dorrit Ph.D. (San Jose State University Research Foundation) Klerman, Elizabeth M.D., Ph.D. (Brigham and Women's Hospital)		
Grant/Contract No.:	NCC 9-58-HFP04201		
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Task Description:	1. Original project aims We aim to develop and evaluate adaptive automation countermeasures to mitigate human performance decrements caused by the stress of sleep deprivation (SD) when supervising robots. We focus on problem solving and decision making tasks that are likely to require active human intervention and be impacted by SD. We also aim to develop methods to measure trust in automation (particularly, modeling the pattern of reliance on automation), to foster appropriate use of automation notices and suggestions, and to track how trust is related to performance and performance degradation. 2. Key findings Our aim is to mitigate effects of SD on crewmembers managing complex operations such as supervisory control of robots and automation. To do this, we need to understand what cognitive processes are highly impacted by SD and what cognitive processes are likely to limit performance in this type of operational context. A large and consistent body of evidence shows that tasks primarily drawing on sustained attention and processing speed in routine tasks are highly vulnerable to SD. However, we expect that higher-level cognitive processes, rather than basic attention, are and should be primarily implicated in future exploration operations. We expect, crewmember cognition may more usefully be spent on decision making, problem solving, or managing the unexpected. Consequently, Dr. Billman performed a literature review during the first year of this project on the effects of SD on higher-level cognitive processes and tasks. The results of this literature review were used to define the decision-making tasks performed by subjects using the robotic supervisory control testbed during the first experiment at Brigham and Women's Hospital (BWH). The first experiment uses the supervisory control testbed to evaluate human-robot interaction in a human exploration mission scenario. In this scenario, resources have been pre-positioned on the planetary surface prior to the arrival of human astronauts. These resources include a habitat with systems powered from batteries. These batteries are charged from solar panels. A humanoid robot R2, developed at NASA Johnson Space Center (JSC), was deployed with these resources. R2 connects batteries to solar panels or to power distribution grids for the habitat. Astronauts in transit to the planet plan and direct the activities of R2 and the smart habitat systems to make the habitat habitable by the time they arrive. Ms. Schreckenghost leads the TRACLabs' development of a testbed for supervisory control of robots to support this scenario. We use the NASA Gazebo simulation of the R2 robot, provided by the Co-Investigator (CoI) Dr. Hambuchen. The Gazebo simulation was modified to include a power generation system based on solar panels that charge batteries, and a power distribution system that takes battery power and distributes it to systems in the habitat. The robot turns knobs on a control panel outside the habitat to connect batteries to solar panels or to power distribution systems. The Gazebo simulation was integrated with TRACLabs's PRIDE procedure automation software to provide supervisory control of the robot. We developed procedures for autonomous execution by the R2 robot that i) connect batteries to solar panels to recharge them, ii) connect batteries to power distribution modules to provide power to the habitat, or iii) disconnect batteries to reserve power. The participant's role is to decide which batteries, solar panels, and power distribution modules should be connected and to plan the sequence in which these components are connected. Dr. Billman leads the San Jose State University (SJSU) effort to develop and test the tasks for the participant to perform during Experiment 1 using the testbed for supervisory control. These tasks were designed to create situations where the expected cognitive deficits associated with SD are likely to occur, based on the literature review. Experiment 1 will assess the impact of SD on higher-level cognitive processes and human trust when directing the R2 robot in the supervisory control testbed. This experiment is being conducted at BWH under the supervision of Dr. Klerman. Experimentation begins in May 2016. 3. Impact of key findings The literature review performed during this year found that the impact of SD on higher-level cognitive processes and tasks is less studied, less consistently found, and harder to compare across studies. Consequently, an expected contribution of our research is improved knowledge about the nature of performance and performance degradation on supervisory tasks when an individual is sleep-deprived. Based on this review we also expect sleep-deprived participants to experience impairments in divergent or flexible thought, which can affect the ability to build and adapt task plans for the robot. Therefore, we have broadened our investigation of adaptive automation countermeasures to include both adaptive alerting identified in the original proposal and technology for adaptive planning of robot tasks. 4. Proposed research plan for next year During Year 1 Ms. Schreckenghost developed initial designs for two types of automation technology countermeasure to these effects – technology for adaptive alerting and technology for adaptive task planning. We will use the results of the first experiment available in September 2016 to inform which of these countermeasures are most likely to mitigate cognitive effects of SD during supervisory control. We then will implement and evaluate technology for the selected countermeasure design in the second experiment to be conducted in Year 2. The Year 2 experiment also will develop objective methods for measuring human trust in these automation countermeasures and investigate the effects of automation trust on task outcome when humans are sleep-deprived. We will conduct Experiment 2 at BWH in early 2017. All work will be complete by May 31, 2017.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	Recent advances in autonomous vehicles makes it likely that in the not-too-distant future drivers will need to supervise their cars while operating autonomously at least some of the time. Many major automobile manufacturers are developing some type of autonomous driving capability [https://]. Also, the proliferation of commercial drones (700,000 in 2015 and over 1 million predicted for 2016) [http://www.npr.org/] means that more, and often less experienced, people will be interacting with semi-autonomous air vehicles. This increases the potential for drone-related accidents. The quantification of the effects of SD on human decision making during supervisory control of semi-autonomous robots, and countermeasures for impaired human-automation/robot interactions will have significant safety and productivity effects for such Earth-based tasks as human interaction with autonomous vehicles and commercial drones. This understanding also can inform the design of autonomous vehicles and commercial drones by identifying the types of adaptations needed to implement countermeasures.

Task Progress:	Task 1. Performed a literature review on the effects of SD on higher-level cognition (Dr. Billman). This literature review found that the impact of SD on higher-level cognitive processes and tasks is less studied, less consistently found, and harder to compare across studies. Our research should improve knowledge about the nature of user performance and performance degradation on supervisory tasks under SD. This review also indicates that sleep-deprived participants experience degraded capacity for divergent or flexible thought, which can affect the ability to plan robotic tasks. In consequence, we broadened our investigation of SD countermeasures to include technology for adaptive task planning. Task 2. Developed a testbed for supervisory control of robots (Ms. Schreckenghost). We modified the NASA R2 robot simulation, from Co-I Dr. Kimberly Hambuchen, to include a power system with solar panels to charge batteries, and power units called DDCUs to distribute battery power to habitat systems. The robot turns knobs on a control panel to connect batteries to solar panels or DDCUs. This simulation was integrated with TRACLabs's PRIDE procedure automation software to provide procedures for autonomous execution by R2 to i) connect batteries to solar panels to recharge them, ii) connect batteries to power distribution, or iii) disconnect batteries. The participant decides which components should be connected and plans the connection sequences. Task 3. Designed supervisory control tasks for experiment 1 (Dr. Billman and Ms. Schreckenghost). These tasks were designed to make it difficult for the sleep-deprived participant i) to self-regulate switching among tasks in accord with allowed choices i.e., perseveration; and ii) to change strategy to suit conditions or to inhibit a dominant strategy, i.e., mental set rigidity. Task 4. Conduct Experiment 1 at BWH (Dr. Klerman). Experiment 1 is ongoing at the time of this report. Participants are selected based on education or work experience in engineering or science. They receive training one week prior to the experiment. The inpatient protocol lasts four calendar days, with five 2-hour sessions using the robotic testbed. Additionally, the participant takes PVT, and saliva and urine are collected. Task 5. Develop designs for technology countermeasures (Ms. Schreckenghost). We identify adaptive alerting as a promising automation countermeasure to the cognitive effects of SD. Adaptive alerting software detects situations with increased potential for errors around attentional lapses and notifies users about them to mitigate their impact. The literature review suggests a second candidate automation countermeasure that seeks to mitigate the anticipated effect of SD on divergent or novel thinking, particularly associated with task planning. For this research, automated task planning refers to selecting and ordering robotic tasks to be efficient while complying with operational constraints.
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