Fiscal Year:	FY 2017	**Task Last Updated:**	FY 02/05/2018
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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 PhD Candidates:	0	**No. of Master' Degrees:**	1
No. of Master's Candidates:	4	**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)		
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Task Description:	This project aims to develop and evaluate adaptive automation countermeasures to mitigate human performance decrements caused by sleep deprivation (SD) conditions when supervising high-autonomy robots and systems. 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 increase our knowledge about the nature of performance and performance degradation on supervisory tasks when an individual is sleep-deprived. During the second year, we conducted another experiment investigating the effects of SD on human performance during robotic supervisory control. We used a similar inpatient protocol in Experiment 2 as used in Experiment 1. We reused two task types developed in the first experiment: i) Efficiency Tasks - discover and use more efficient task order; and ii) Constraint Tasks - recall and use equipment status changes. Additionally, two countermeasures were developed to mitigate the effects of SD on human performance when supervising robots, and evaluated in the second experiment. The task planning countermeasure software was developed to aid short-term memory when sleep-deprived by allowing users to build and execute new sequences of automation tasks on-the-fly. This countermeasure should improve task accuracy and timing. The adaptive alerting countermeasure was developed to remind users to perform infrequent but important supervisory tasks when sleep-deprived. This countermeasure should reduce the time automation waits for human intervention and thus reduce overall task timing. During Experiment 1 we experienced data loss due to unexpected variation in the way subjects interpreted and responded to instructions. Tasks needed to be sufficiently constrained that successful performance would likely generate a predictable stream of events, thus making scoring of the behavior streams feasible and results across subjects comparable. We redesigned core tasks from Experiment 1 for Experiment 2 and were overall successful in providing the intended, complex task sequences. The core tasks were executed as planned in Experiment 1 with essentially very low data loss. Data were collected from 8 participants in Experiment 2. We had expected 15 participants for this experiment. The number of participants was less than expected because a delayed project start reduced the amount of time we had to perform Experiment 2 and analyze data from it. We also experienced difficulty in finding subjects with the necessary education and computer literacy to serve as rough astronaut surrogates. We report on results from the core tasks and from the tasks assessing use of the task planning countermeasure. The factors for core tasks were sleep status (rested versus sleep deprived) and repetition (first versus second exposure to the type of task), with assignment of rested-first or rested-second counterbalanced across users. We have an n of 8 with large individual differences, hence low sensitivity, and we have done no inferential statics. Rather, we looked for suggestive patterns in performance. For Core tasks, we looked for patterns suggesting impact of SD and repetition on flexible reasoning. For task planning countermeasure assessment, we looked for patterns concerning how planner use influenced performance. We did not analyze data from use of the adaptive alerting countermeasure, because of reduced time available to conduct Experiment 2 and analyze data from it. Our ability to detect effects of SD or Trial is limited by small n and large individual differences. We found some evidence of effects of SD on performance for one core task. The most suggestive pattern was found on the accuracy of performing a Constraint Task. For this task, the subject should devise a sequence of tasks that connect batteries to solar panels while complying with a new safety constraint designating how many batteries can be connected to a solar panel. Four of the eight users showed sensitivity to the constraint at some point, two of these four respected the constraint on both trials. Two users, however, did well on the first trial (which was also rested) but did not respect the constraint later when they were sleep deprived. That is, they showed a decrement in performance when sleep deprived, even though that was their second exposure to this constraint task. We consider this pattern of performance to be consistent with the hypothesis that SD reduces the chance a user will correctly integrate information that requires modifying the way a user is doing the task. This is an intriguing pattern though our n is small, suggesting that further investigation may be warranted. We assessed use of the task planning countermeasure by requiring users to work on two tasks at once, the context where we expected a benefit from being able to automatically run a sequence of procedures. The primary task was executing a series of robot procedures automatically and the secondary task was manually identifying the most efficient paths for a Rover using a diagram of possible paths. The primary dependent variables were how much work could be done on these tasks in 12 minutes. We looked at data from three occurrences of this task. Summarizing across these occurrences, users who were re-using their plans, or had planned outside the time window had some advantage in number of tasks completed over users who planned within the time window. Those in the Plan re-use task also had the lowest number of errors on the secondary task. For all tasks considered, slips are low, with little impact of plan use. Slips were defined as errors due to insertion of extra tasks, skipped tasks, unnecessary task repetition, or mis-ordered tasks. There may be a trend for slips to increase over the course of a session. A large amount of data was collected in this project, but very limited time was available to analyze these data. Further analyses of these data are merited.
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. Also, the proliferation of commercial drones means that more, and often less experienced, people will be interacting with semi-autonomous air vehicles, which 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. Analyzed data from Experiment 1: We analyzed performance data collected during the first experiment conducted in Year One. Data were collected from 14 participants performing the following three task types (performed in 5 tasks) to assess human decision-making and work management under SD: i) Ordering Tasks: Follow explicit task order rules; ii) Efficiency Tasks: Discover and use more efficient task order; iii) Constraint Tasks: Recall and use equipment status changes. We found effects of SD on timing of two of these tasks – a constraint task and an efficiency task. Task 2. Developed adaptive automation countermeasure software: We developed technology for automation countermeasures are intended to mitigate SD effects on human performance when supervising robots. The adaptive alerting countermeasure intends to aid recall to perform supervisory tasks when sleep-deprived by alerting the user when the robot needs human intervention. The adaptive planning countermeasure intends to aid short-term memory when executing complex sequences of procedures by supporting users in planning robot activity sequences that can be built on the fly and executed automatically. Task 3. Designed supervisory control tasks for experiment 2: We revised the core tasks from Experiment 1 intended 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. We added new tasks to investigate how the automation countermeasures affected performance under sleep deprived conditions. Each participant used the countermeasure tools one of two sessions, half in the earlier and half in the later session. Task 4. Conduct Experiment 2 at Brigham and Women's Hospital (BWH): Participants were selected based on education or work experience in engineering or science. They received 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 Psychomotor Vigilance Test (PVT), and saliva and urine are collected. Task 5. Analyzed data from Experiment 2: We analyzed performance data collected for the core tasks requiring constraint awareness and compliance or task efficiency, and for the tasks assessing use of the automation countermeasure tools. We have an n of 8 with large individual differences, hence low sensitivity, and we did no inferential statics. Rather, we looked for suggestive patterns in performance. For core tasks, we looked for patterns suggesting impact of sleep deprivation (and also repetition) on flexible reasoning. For task countermeasure assessment, we looked for patterns concerning how use of the planner influenced performance. Overall, we found very little evidence of effects from sleep status. The most suggestive pattern was found on one of the core constraint tasks.
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