

Fiscal Year:	FY 2014	Task Last Updated:	FY 01/29/2014
PI Name:	Sebok, Angelia M.S.		
Project Title:	S-PRINT: Development and Validation of a Tool to Predict, Evaluate, and Mitigate Excessive Workload Effects		
Division Name:	Human Research		
Program/Discipline:	HUMAN RESEARCH		
Program/Discipline--Element/Subdiscipline:	HUMAN RESEARCH--Space Human Factors Engineering		
Joint Agency Name:	TechPort:	Yes	
Human Research Program Elements:	(1) SHFH :Space Human Factors & Habitability (archival in 2017)		
Human Research Program Risks:	(1) HSIA :Risk of Adverse Outcomes Due to Inadequate Human Systems Integration Architecture (2) Sleep :Risk of Performance Decrements and Adverse Health Outcomes Resulting from Sleep Loss, Circadian Desynchronization, and Work Overload		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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Comments:			
Project Type:	GROUND	Solicitation / Funding Source:	2010 Crew Health NNJ10ZSA003N
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No. of Post Docs:		No. of PhD Degrees:	
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No. of Master's Candidates:	2	No. of Bachelor's Degrees:	
No. of Bachelor's Candidates:	2	Monitoring Center:	NASA ARC
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Flight Program:			
Flight Assignment:			
Key Personnel Changes/Previous PI:	There are no key personnel changes to report in Year 2.		
COI Name (Institution):	Sargent, Robert (Alion Science And Technology Corporation) Wickens, Christopher (Self) Clegg, Benjamin (Colorado State University)		
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	<p>This proposal describes a plan to research, develop, and validate a prototype model-based tool for human performance researchers, automation system designers, mission planners, and astronauts to evaluate predicted astronaut performance on long-duration space missions during unexpected workload transition scenarios. The tool will enable users to identify the effects of astronaut fatigue, automation system design, and task factors on astronaut performance in off-nominal events. The proposed tool, the Space Performance Research Integration Tool (S-PRINT), will leverage a human performance modeling environment, the Improved Performance Research Integration Tool (IMPRINT), and tailor it to space mission applications.</p> <p>IMPRINT was developed for the Army Research Laboratory, and is available, free of charge, to U.S. government agencies. IMPRINT includes algorithms to study performance shaping factors such as fatigue, training, and use of protective clothing with human performance models that include workload.</p> <p>S-PRINT is being developed based on extensive literature reviews and meta-analyses, in which the team systematically evaluated human-in-the-loop research to identify and quantify factors in long-term space missions that affect astronaut workload, fatigue, and performance. The results of these meta-analyses are being used to update IMPRINT algorithms so they more accurately reflect space-specific conditions. The S-PRINT tool is being developed so it can be used to evaluate performance in missions that are being planned or missions that are currently underway.</p> <p>The team has identified a scenario of interest for a prototype application of the tool. The scenario includes an astronaut manually controlling a robotic arm when an unannounced failure occurs in the environmental process control system. The process control failure results in a cascade of events that eventually cause an annunciated alert. When operators notice the process control failure, they will need to prioritize among the different tasks. We are currently working with subject matter experts (SMEs) to perform task analyses and develop human performance models to reflect those situations. SMEs will review the models and their predictions form an early validation study. The team will also perform an empirical, human-in-the-loop validation study, and the validation results will be used to refine the models. Further, the team is conducting focused human-in-the-loop studies to address specific questions that were not answered in the meta-analyses.</p> <p>Our scenario development and research efforts focus specifically on situations that result in workload transitions (e.g., automation failures, other off-nominal events), placing the astronauts in potential overload situations. These conditions, when addressed by fatigued astronauts, constitute worst case scenarios and require specific, in-depth investigation. One particular goal of this project is to develop a prototype tool that is both usable and useful for analysts, allowing them to easily modify scenarios and evaluate the effects of different factors on mission performance. This tool will provide data entry screens that guide the user through the process of building a scenario. It will allow the researchers to specify numerous relevant factors, e.g., operators, tasks, equipment, automation support, environmental conditions, and sleep schedules. The output of the model run will include parameters of interest such as perceived workload, fatigue, time to initiate tasks, time to complete tasks, task accuracy, task failures (representing human error), results of task failures, and overall mission success. The objective of this research is to develop a validated model-based tool to help NASA researchers evaluate potential long-duration missions, identify vulnerabilities, and test potential mitigation strategies to help ensure effective performance and safe space missions.</p>
Task Description:	
Rationale for HRP Directed Research:	<p>The S-PRINT project includes research, modeling, and empirical investigations of human performance in unexpected workload transition situations. In particular, it examines performance under conditions in which operators are fatigued, and have previously experienced highly reliable automation. The tool will allow users (mission planners, automation system designers, astronauts, human performance specialists) to evaluate different conditions (of operator fatigue, system design factors, and task factors) that affect performance, to examine the impact of potential mitigation techniques.</p> <p>In developing models of operator workload and cognitive performance, we conducted extensive meta-analyses investigating the effects on operator performance of the following factors: 1) fatigue due to sleep deprivation, sleep restriction, circadian cycle, and sleep inertia; 2) human automation interaction, including design factors that affect complacency, detection and diagnosis of faults, and implementation of corrective actions; 3) overload and multitasking. These meta-analyses are being used to develop the S-PRINT plug-in to the IMPRINT human performance modeling tool. Because IMPRINT is a Department of Defense tool, the plug-in developed for it can be used by Government entities to examine human performance in a variety of relevant conditions.</p>
Research Impact/Earth Benefits:	<p>S-PRINT will allow users to evaluate other types of missions (e.g., military, process control, medical, aviation) in which fatigued operators work with complex automation and potentially have to deal with unexpected, high-workload situations. S-PRINT will provide a flexible modeling tool (IMPRINT) with empirically based algorithms to predict operator performance (through S-PRINT). Our models of fatigue, human response to automation failures, and task management during overload are applicable in all of these environments.</p> <p>In addition to the model development efforts, this research includes a significant component of empirical, human-in-the-loop research. These experimental studies address human-automation interaction, operator multitasking, and performance in unexpected automation failure scenarios. This empirical research will contribute to the state of knowledge in fields such as human-automation interaction and operator performance in complex operations.</p>
	<p>The objective of this research, S-PRINT, is to develop a software tool and empirically based guidelines that support human performance researchers, mission planners, automation designers, and astronauts in long-duration missions. Specifically, the products from this research will help users to (a) anticipate and avoid potential problems related to unexpected workload transitions by identifying the expected effects of operator fatigue, automation system design, and task factors on overload performance, and (b) assure that systems can be designed in such a way as to minimize transient or longer-term impacts on performance in space exploration missions.</p> <p>The project consists of three main lines of work: 1) literature review and meta-analyses, 2) S-PRINT model and tool development, and 3) empirical data collection and validation studies.</p> <p>Literature Review and Meta-Analyses</p> <p>The literature review and meta-analyses were conducted to identify and evaluate factors that affect astronaut</p>

performance on long-duration space missions. In our literature review effort, we identified three primary areas of research: 1) fatigue and underload effects on performance, 2) human-automation interaction, including factors such as automation reliability and operator complacency, and 3) overload, multitasking, and operator strategies for performing tasks in these conditions. These three areas were researched in parallel to provide a qualitative understanding of the issues (goal of the literature review), and to provide empirically based data to inform human performance model development (goal of the meta-analyses).

Progress: This task was completed at the end of Year 1. Results were provided in a report delivered to NASA on April 8, 2013: Space Performance Research Integration Tool (S-PRINT): Development and Validation of a Model-Based Tool to Predict, Evaluate and Mitigate Excessive Workload Effects - Year 1 Literature Review and Meta-Analyses Summary Report.

S-PRINT Model and Tool Development

The S-PRINT model and tool development area includes three main subtasks: 1) S-PRINT tool development, 2) human performance model development, and 3) implementation of sub-models, algorithms, and performance shaping factors from the meta-analyses.

Progress: This task is on-going and will continue throughout Year 3. We have developed a plan for the S-PRINT tool design, and are currently developing a prototype version of the tool. S-PRINT will be contained within the Improved Performance Research Integration Tool (IMPRINT), a human performance modeling tool that Alion has developed and maintains for the Army Research Laboratory. IMPRINT allows users to build computational models to predict operator performance in complex scenarios. S-PRINT will allow users to develop and evaluate scenarios using a particular model of operator performance. S-PRINT will provide one default model, but will include the capability for users at NASA to build their own custom models using IMPRINT. S-PRINT provides an easy-to-use interface that allows users to create, run, and compare scenarios using already-existing (upon delivery) IMPRINT models. By changing input parameters regarding the astronaut fatigue situation, automation system design, and task characteristics, S-PRINT users can create literally thousands of scenarios. The output from these scenarios can be compared to identify sleep mitigations, automation design changes, or task factor changes that can be adjusted to provide better performance.

We have identified a scenario for developing the human performance model. This includes an astronaut working with a remotely manipulated robotic arm and monitoring an environmental process control system. A fault occurs in the process control system, and rapidly becomes a high-workload off-nominal event. We are currently in the process of developing the model of the scenario, and collecting data from NASA trainers, astronauts, and from our robotics and process control simulations.

Task Progress:

The third task in the tool and model development area – implementing the sub-models, algorithms, and performance shaping factors from the meta-analyses into the modeling tool – is currently ongoing. The fatigue meta-analysis provided algorithms that specify performance degradations based on sleep deprivation (hours of continual wakefulness), restricted sleep (consecutive nights with less than 6 hours sleep/night), circadian cycle effects, and sleep inertia (performance upon immediate awakening). Some of these algorithms have already been included into IMPRINT, and others are being reviewed for inclusion. The second area of the meta-analyses, human-automation interaction, addresses specific questions regarding the effects of different automation design factors on operator performance when the automation unexpectedly fails to operate as anticipated (creating a workload transition). These factors include: reliability of automation (inducing complacency), failure type (e.g., no information provided versus misleading information given), salience of alerts, transparency of the interface (e.g., the extent to which the automation provides support for the operator's mental model, as opposed to simply providing data that the operator must interpret), degree of automation, and availability of guidance in the interface for supporting operator action implementation. These factors are currently being evaluated in project-specific empirical studies.

From the meta-analysis of task overload and multitasking, we have developed a model of operator task selection and task shedding in overload. Factors such as task difficulty, salience (the presence of a reminder), priority, and engagement all affect the probability that an operator will select or shed a given task. We are currently implementing this model in IMPRINT, and are performing empirical studies to investigate the relative weightings of these factors and the presence and significance of a fifth factor: nearness to task completion. The effects of these task-specific factors on operator task selection, and their interaction with fatigue, are currently being investigated through project-specific empirical studies.

Empirical Data Collection and Validation Studies

The data gathering and validation studies being conducted in this effort are a set of ground-based human-in-the-loop (HITL) studies performed at Colorado State University (CSU), specifically designed to provide data for model development.

Progress: This task is currently ongoing, and will continue through Year 3.

Four experiments have been performed to investigate operator performance in working with automation, and in multitasking conditions. In addition, we are planning three further experiments, to address gaps in the meta-analyses. These experiments will provide data regarding the effects of automation design on operator performance, the effects of task factors on operator multi-task performance, and the interaction of automation design with fatigue and (potentially) the interaction of multitasking with fatigue. The experimental studies are also providing data to populate the human performance model: times to complete tasks, probability of failure on a given task, and performance distributions on the tasks. A larger study will be conducted in Year 3. The data gathered in this study will be used for model validation.

Summary

The S-PRINT research project is proceeding on schedule. We have performed literature reviews and meta-analyses in Year 1, and in Year 2 we have begun tool development, model development, and targeted experimental studies to support model development. In Year 3 we will continue to refine the tool and model, and implement model updates based on the experimental results. We will perform a validation study and update the model accordingly.

Bibliography Type:

Description: (Last Updated: 09/07/2020)

Articles in Peer-reviewed Journals	Gutzwiller RS, Clegg BA, Blitch JG. "Part-task training in the context of automation: current and future directions." American Journal of Psychology. 2013 Winter;126(4):417-32. http://www.jstor.org/stable/10.5406/amerjpsyc.126.4.0417 , accessed 1/29/14 ; PubMed PMID: 24455809 , Dec-2013
Articles in Peer-reviewed Journals	Hutchins SD, Laux L, Wickens CD, Sebok A. "The effect of continuous wakefulness on complex cognitive task performance: a quantitative synthesis of research." Proceedings of the Human Factors and Ergonomics Society Annual Meeting. 2013 Sep;57(1):793-7. 57th Annual Meeting of the Human Factors and Ergonomics Society, San Diego, CA, September 30-October 4, 2013. http://dx.doi.org/10.1177/1541931213571173 , Sep-2013
Articles in Peer-reviewed Journals	Sebok A, Wickens C, Sargent R. "Using meta-analyses results and data gathering to support human performance model development." Proceedings of the Human Factors and Ergonomics Society Annual Meeting. 2013 Sep;57(1):783-7. 57th Annual Meeting of the Human Factors and Ergonomics Society, San Diego, CA, September 30-October 4, 2013. http://dx.doi.org/10.1177/1541931213571171 , Sep-2013
Articles in Peer-reviewed Journals	Wickens C, Santamaria A, Sebok A. "A computational model of task overload management and task switching." Proceedings of the Human Factors and Ergonomics Society Annual Meeting. 2013 Sep;57(1):763-7. 57th Annual Meeting of the Human Factors and Ergonomics Society, San Diego, CA, September 30-October 4, 2013. http://dx.doi.org/10.1177/1541931213571167 , Sep-2013