Fiscal Year:	FY 2023	**Task Last Updated:**	FY 08/31/2023
PI Name:	Strangman, Gary E Ph.D.		
Project Title:	Quantifying and Predicting Operationally-Relevant Performance in a Long-Duration Spaceflight Analog		
Division Name:	Human Research		
Program/Discipline:			
Program/Discipline--Element/Subdiscipline:	HUMAN RESEARCH--Behavior and performance		
Joint Agency Name:		**TechPort:**	No
Human Research Program Elements:	(1) **HFBP**:Human Factors & Behavioral Performance (IRP Rev H)		
Human Research Program Risks:	(1) **BMed**:Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders (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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Zip Code:	02129-2020	**Congressional District:**	7
Comments:			
Project Type:	GROUND	**Solicitation / Funding Source:**	2015-16 HERO NNJ15ZSA001N-ILSRA. Appendix F: International Life Sciences Research Announcement
Start Date:	08/01/2016	**End Date:**	04/30/2024
No. of Post Docs:	1	**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:**	NASA JSC
Contact Monitor:	Whitmire, Alexandra	**Contact Phone:**	
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Flight Program:			
Flight Assignment:	NOTE: End date changed to 4/30/2024 per V. Lehman/JSC (Ed., 5/16/23) NOTE: End date changed to 4/30/2023 per NSSC information (Ed., 5/2/22) NOTE: End date changed to 4/30/2022 per NSSC information (Ed., 4/12/21) NOTE: End date changed to 4/30/2021 per NSSC information (Ed., 5/4/2020) NOTE: Changed end date to 9/30/2020 per L. Juliette/HRP (Ed., 2/19/2020) NOTE: Extended to 1/31/2020 per K. Ohnesorge/HRP JSC (Ed., 5/24/18) NOTE: Element change to Human Factors & Behavioral Performance; previously Behavioral Health & Performance (Ed., 1/18/17)		
Key Personnel Changes/Previous PI:	October 2023 Update: Per the PI, Dr. Stijn Thoolen has left the project (Ed., 10/12/23).		

COI Name (Institution):	Zhang, Quan Ph.D. (Massachusetts General Hospital) Ivkovic, Vladimir Ph.D. (Massachusetts General Hospital)
Grant/Contract No.:	NNX16AO30G
Performance Goal No.:	
Performance Goal Text:	
Task Description:	Exploration spaceflight missions will expose crewmembers to many risks that could affect their performance and mission success. Minimizing such risks will require identifying and validating objective indicators of behavioral health and performance (BMed2 Gap), understanding the contribution of sleep loss on individual behavioral health (Sleep2 Gap), and identifying countermeasures that can reduce these risks (BMed1, BMed6, and Sleep9 Gaps). Currently the Robotic On-Board Trainer (ROBoT) is used operationally by astronauts both on the ground and on the International Space Station (ISS) to practice Canada Arm activities. Our group is helping adapt ROBoT for research use and for quantitative performance assessment. In addition, our group is developing and testing NINscan-SE: a multi-use system for measuring brain and physiological function. Both ROBoT and NINscan-SE are being characterized and validated in our laboratory, and will undergo analog feasibility testing during the Human Exploration Research Analog (HERA) C4 and C5 campaigns. In this project, we will deploy both systems to: Aim 1: Characterize operational task performance changes during 45-day HERA missions, including the roles of time-in-mission, workload, sleep debt, and operational emergencies. Aim 2: Characterize brain and systemic physiology changes during 45-day HERA missions, including the roles of time-in-mission, workload, sleep debt, and operational emergencies. Aim 3: Identify physiological or behavioral variables that predict operational performance. Aim 4: Quantify the influence of behavioral health countermeasures on both operational performance and (neuro)physiological measures. To achieve these aims, we will recruit up to 32 crewmembers from eight 45-day missions in the HERA facility during Campaigns 4 and 5, plus up to 32 control subjects. HERA and control participants will all perform ROBoT tasks plus undergo physiological monitoring 2x/week, on matching schedules, thus enabling us to differentiate changes in operational performance due to practice over time from any changes due to HERA sequestration. In addition, two “unexpected operational emergency” events will be introduced in the first and last weeks of each HERA mission. These will consist of an acute need to capture a wayward satellite traveling near the limits of Canada Arm capabilities. We will also work with the Behavioral Health and Performance (BHP) [Ed. note: Element is now known as Human Factors and Behavioral Performance] Element and other HERA investigators to coordinate ROBoT and physiological data collection before, during, and after one or more countermeasure (CM) deployments during the HERA missions. CM(s) may include a lighting intervention, a Virtual Space Station-based behavioral intervention, diet, exercise or some other intervention. The experimental design will depend on the nature of the CM. We will test hypotheses that the CM(s) generate detectable changes in ROBoT performance and rest/task (neuro)physiology recordings. We will also compare ROBoT performance to the standardized Behavioral Core Measures (BCM), if possible. The knowledge-deliverables of this project will describe: (i) changes in operationally-relevant (ROBoT) performance during the HERA mission in a well-controlled analog study of substantial size; (ii) changes in cerebral and systemic physiology associated with HERA mission parameters as well as operational performance; (iii) identification of potential predictors of future ROBoT performance; and (iv) the influence of the investigated countermeasure(s) on operational performance and physiology.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	The ROBoT system—and the HERA isolation protocol—are quite specific to NASA spaceflight operations and hence have relatively few direct Earth applications. However, the ROBoT spacecraft-capture simulations represent a highly skilled, complex operational performance task. It could thus be used as a comparison task in concert with detailed cognitive testing to help dissect the cognitive components complex tasks as well as the influence of other physiological stressors (e.g., sleep deprivation, alcohol consumption, medical radiation) on the performance of such tasks. Use of different complex tasks with the same approach could be useful in assessing and predicting performance in a wide range of other operational environments (diving, pilots, military, surgeons, etc.). Regarding NINscan-SE, no current NIRS (near-infrared spectroscopy), EEG, or polysomnography device has both the portability and the multi-use features of the system we will be deploying. This system could thus have substantial novel Earth applications. Hospital monitoring applications could include long-duration, non-invasive brain monitoring in the NeuroICU following stroke or traumatic injury, for which no similar technology exists. Real-time, in-office brain activation assessment could also be supported, for assessment of psychiatric states, for monitoring the neural effects of cardiovascular or psychoactive drugs or other therapies, or for brain monitoring during rehabilitation. Mobile monitoring could perhaps have an even larger impact outside the hospital setting. A wearable monitor would enable ambulatory syncope monitoring, or multi-parameter ambulatory epilepsy monitoring. If deployed in emergency settings, NINscan-SE could potentially be used to detect cerebral or abdominal hemorrhage, ischemia, and/or cortical spreading depression by first responders. Home monitoring uses include various sleep disorders, as well as various commercial possibilities.

Task Progress:	The overall goal of this project is to assess operationally relevant behavioral performance over 45-day isolation and confinement periods in the Human Exploration Research Analog (HERA), as well as associated neurophysiological status during HERA missions. Operational performance is being evaluated using the ROBoT-r task—an operationally used track-and-capture task for grappling incoming resupply vehicles using Canadarm2. The ROBoT-r task was modified for research use as part of the separate Behavioral Core Measures project by Drs. Strangman and Ivkovic. Brain and systemic physiological assessments include resting-state connectivity and functional brain activation during the ROBoT-r task trials using our near-infrared spectroscopy and imaging (NIRS/NIRI) based NINscan devices, as well as electrocardiogram (EKG), electroocoulogram (EOG) and electroencephalogram (EEG) during ROBoT-r performance. Progress over the past year is detailed below. HERA Data Collection: Having completed n=36 subjects from HERA Campaigns 4 and 5, the primary task over the past year has been to recruit and run control subjects to match the HERA participants. To date, we have completed running n=24 control subjects, with recruitment remaining slow (for a 9-week, 26-session experiment) but ongoing. HERA Data Analysis: To date, all analyses remain preliminary, given the ongoing recruitment of control subjects. However, a number of features have been clearly identified. • Weighted scores improve steadily and significantly throughout the ~60-day pre-, during-, and post-HERA periods, representing improved accuracy at the point of contact between Canadarm2 and the HTV-II vehicle. The proportion of successful captures also increases over this period. • Time required to complete vehicle capture decreases steadily and significantly over this same period. Increased speed combined with improved performance is a hallmark of learning, which appears to continue throughout the 60-day period (which represents ~10-12 hours of hands-on ROBoT-r performance). • Performance is significantly affected by run difficulty, with each step-up in difficulty resulting in significantly poorer and slower performance. • There were significant differences in overall performance levels across the different missions/crews. • Preliminary physiological data from NINscan demonstrate significant differences between HERA crews and controls in heart rate (HERA>Controls). Both groups exhibited changes in heart rate, as well as frontal pole and dorsolateral prefrontal brain activation within runs, suggesting progressive brain activation as the more challenging end-of-run phase approached. In addition to the above findings, we have conducted analyses to examine the effects of the countermeasures (CMs) deployed in HERA Campaign 4. These analyses suggest the following: • Confinement in HERA led to a significant performance impairment, equivalent to an increase in task difficulty of approximately 30%. • The dynamic lighting schedule—with enriched blue light in the morning and enriched red light in the evening (as compared to standard lighting)—mitigated the majority of the performance deficit associated with confinement in HERA. • The experimental diet—which included a 25% enrichment of omega-3 fatty acids, lycopene, flavonoids, fruits, and vegetables—had no significant improvements nor decrements in ROBoT-r performance. Once all physiological datasets have been fully cleaned and preprocessed, we will conduct final statistical modeling to address our three physiologically related specific aims: (Aim 2) characterize brain and systemic physiology changes during HERA missions, (Aim 3) identify predictive brain and systemic physiological biomarkers for ROBoT-r performance, and (Aim 4) quantify the influence of behavioral health countermeasures on (neuro)physiological measures. Dissemination: The findings to date from this study were presented at the virtual Human Research Program (HRP) Investigators' Workshop (IWS) conference in early February 2023. One peer reviewed paper has been published. A second manuscript that examines the effects of countermeasures in HERA C4 is scheduled to be submitted for peer-review soon. A third manuscript looking at the ability to predict ROBoT-r performance from Cognition scores is currently under author review. Supplement: This project includes a supplement to investigate the role of transcranial electrical stimulation (tES) on ROBoT-r performance, both acutely and over the 2 days immediately following stimulation. This double-blind crossover design experiment is currently underway, approaching 50% complete.
Bibliography Type:	Description: (Last Updated: 04/26/2024)
Abstracts for Journals and Proceedings	Ivkovic V, Thoolen S, White BM, Zhang Q, Rahman SA, Lockley SW, Strangman GE. "Operational Performance Measures: Effects of Isolation and Confinement, Altered Lighting, Habitat Volume, and Enhanced Nutrition on ROBoT-r in HERA." 2023 NASA Human Research Program Investigators' Workshop, Galveston, Texas, February 6-9, 2023. Abstracts. 2023 NASA Human Research Program Investigators' Workshop, Galveston, Texas, February 6-9, 2023. , Feb-2023
Abstracts for Journals and Proceedings	White B, Ivkovic V, Zhang Q, Strangman GE. "BRAIN-STIM: Preliminary Investigations of transcranial electrical stimulation (tES) Effects on Operational Performance, Neurophysiology and Behavior." 2023 NASA Human Research Program Investigators' Workshop, Galveston, Texas, February 6-9, 2023. Abstracts. 2023 NASA Human Research Program Investigators' Workshop, Galveston, Texas, February 6-9, 2023. , Feb-2023
Articles in Peer-reviewed Journals	Scarpa J, Parazynski S, Strangman G. "Space exploration as a catalyst for medical innovations." Front Med (Lausanne). 2023 Jul 19;10:1226531. https://doi.org/10.3389/fmed.2023.1226531 ; PubMed PMID: 37538310; PubMed Central PMCID: PMC10395101 , Jul-2023