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| **Fiscal Year:** | FY 2023 | **Task Last Updated:** | FY 03/28/2023 |
| **PI Name:** | Moudy, Sarah Ph.D. | | |
| **Project Title:** | Development of Sensorimotor Fitness for Duty Assessments Using Ground Analogs | | |
| **Division Name:** | Human Research | | |
| **Program/Discipline:** | | | |
| **Program/Discipline--Element/Subdiscipline:** | | | |
| **Joint Agency Name:** | | **TechPort:** | No |
| **Human Research Program Elements:** | (1) **HHC**:Human Health Countermeasures | | |
| **Human Research Program Risks:** | (1) **Sensorimotor**:Risk of Altered Sensorimotor/Vestibular Function Impacting Critical Mission Tasks | | |
| **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:** | Directed Research |
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| **No. of Master's Candidates:** | 0 | **No. of Bachelor's Degrees:** | 0 |
| **No. of Bachelor's Candidates:** | 0 | **Monitoring Center:** | NASA JSC |
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| **Flight Program:** | | | |
| **Flight Assignment:** | | | |
| **Key Personnel Changes/Previous PI:** | This investigation is a continuation of a Directed Research project with the same name under PI Marissa Rosenberg. Dr. Rosenberg has left NASA. The new PI is Sarah C. Moudy, Ph.D. with KBR/Aegis Aerospace. Millard Reschke, Ph.D. has retired from NASA so he no longer serves as Co-Investigator. | | |
| **COI Name (Institution):** | Wood, Scott Ph.D. ( NASA Johnson Space Center )<br>Peters, Brian Ph.D. ( NASA Johnson Space Center )<br>Clark, Torin Ph.D. ( University of Colorado, Boulder )<br>Schubert, Michael ( Johns Hopkins University ) | | |
| **Grant/Contract No.:** | Directed Research | | |
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| **Performance Goal Text:** | | | |

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| Task Description: | The first aim will develop a Sensorimotor Disorientation Analog (SDA) that can provide different levels of acute disorientation through combined vestibular, visual, and proprioceptive disruptions. The SDA will be used to increase the range of performance, simulating the moderate-to-severe performance decrements observed postflight. The levels of SDA will be titrated and validated by 1) using feedback from experienced astronauts, and 2) comparison to gold standard measures that have a wealth of spaceflight data at different time points during recovery. Astronaut postflight experience will provide a more realistic starting point for validation of the SDA. Referencing existing postflight data from the gold standard measures will also help us characterize how each magnitude of SDA compares to recovery from long-term microgravity exposure.<br>The second aim will assess the suitability of a proposed set of sensorimotor assessment tasks, or measures that would be feasible within the limited time, resources, and space of a lunar/Martian lander. The assessment tasks should aid in progressive adaptation to the novel gravitational environment, provide opportunities to develop strategies to recover from off-nominal body positions, and mimic operational tasks such that crew can self-assess their potential ability to complete their missions. We will obtain performance of the sensorimotor assessment tasks at varying levels of the SDA magnitude to map sensorimotor ability to the probability of completion of operational performance measures.<br><br>Our third aim involves up to 90 minutes of prolonged +3GX centrifugation to mimic the vestibular alterations observed after gravity transitions. Immediately after egress from the centrifuge, subjects will perform a subset of the sensorimotor assessment tasks followed by the operational performance tasks. We will map performance in sensorimotor assessment tasks to performance in operational performance measures, similar to aim two.<br><br>Our fourth aim will utilize the NASA Johnson Space Center (JSC) Active Response Gravity Offload System (ARGOS) to characterize the effects of a reduced gravity load on balance-related exploration and operational measures.<br><br>The fifth and final aim will build on the lunar landing simulations that will be developed for the Manual Crew Override study (PI: Wood) and the human lander systems training simulations to support the Flight Operations Directorate for Artemis mission training. Similar to Aim 1a, this aim anticipates working with experienced crewmembers to satisfy some of the training for generic lunar landing tasks. The study will involve two pre-test familiarization sessions focused on developing proficiency to perform the landing task through multiple landings with both the full simulator and the Just In Time (JIT) trainer platform. Following recommended guidelines for Artemis sustaining mission, crewmembers will then wait 75 days before performing the same lunar landing following a g-state analog (sustained centrifugation). The outcome of this aim is to characterize the relationship between the performance on the JIT platform with post-centrifuge lunar landing performance to inform what performance threshold is required to mitigate risk associated with vertigo and disorientation with manual crew override during landings.<br><br>The main deliverables from this project will be recommended sensorimotor assessments for extravehicular activity (EVA) operations that provide a quantitative index of readiness to perform key operational tasks and validation of lunar landing simulations for training manual crew override during landings.<br><br>NOTE: Per the Principal Investigator (PI): During the first project year, Aim 1c was removed from the project (Ed., 4/18/23). Aim 1c was to examine a large number of proposed sensorimotor assessment tasks in an effort to reduce the set of tasks to those that are the most sensitive to changes in sensorimotor disruption via the SDA. |
| Rationale for HRP Directed Research: | This research is directed because it contains highly constrained research. This project is in direct response to the baselined Human Research Program (HRP) Path to Risk Reduction milestone of providing updates to the NASA Fitness For Duty Standards. The new standards should be tied to fitness for duty for exploration tasks and provide a quantitative index of readiness to perform key exploration tasks. This research effort will leverage expertise based upon HRP-funded flight research investigations including Functional Tasks Test, Field Test, Standard Measures, and Manual Control, as well as MedB computerized dynamic posturography. This project will leverage critical mission tasks previously established by Ryder et al. ("A novel approach for establishing fitness standards for occupational task performance." Eur J Appl Physiol, 2019) for standards related to the risk of reduced muscle mass, strength, and endurance. This project must also leverage experience with vestibular spaceflight analogs (e.g., Galvanic vestibular stimulation, sustained 3Gx centrifugation) to characterize how the deconditioned state following G-transitions (e.g., postural instability, motion sickness, head movement restrictions) map to functional performance. |
| Research Impact/Earth Benefits: | This research addresses the Risk of Altered Vestibular/Sensorimotor Function Impacting Critical Mission Tasks (Sensorimotor Risk) and associated research gaps from NASA’s Human Research Roadmap. The development of sensorimotor assessments for EVA and manual control addresses each gap associated with the characterization of the effects of spaceflight on the sensorimotor and neuro-vestibular systems, including postural control and locomotion (Gap SM-101), manual control (Gap SM-102), spatial orientation and motion sickness (Gap SM-103), and other brain functions such as sleep, cognition, attention (Gap SM-104).<br>This project is in direct response to the baselined Human Research Program (HRP) Path to Risk Reduction milestone of defining sensorimotor assessments that can provide a quantitative index of readiness to perform key exploration tasks. The Flight Operations Directorate has identified the need for better sensorimotor assessment tools that would protect against hazards of performing operational tasks too soon following gravitational transitions. The project outcomes will address this recommendation by providing a validated set of sensorimotor assessment tasks that will 1) allow for self-assessment when communication with ground support may be limited or delayed and 2) provide progressive adaptation to the novel gravitational environment.<br><br>For Earth-based benefits: The sensorimotor community has a need for simple assessment tasks that could be used clinically, through telemedicine, or by the patient alone. These tasks could be used to help in self-determination of the patient’s sensorimotor ability to perform daily activities and/or guide recovery of vestibular-impaired patients. |

**Task Progress:**

During the first project year, Aim 1a and Aim 1b were completed; Aim 1c was removed from the proposal, and Aim 2 is underway.
Aim 1a: We completed an exploratory study to gather subjective feedback from five previously flown astronauts (1 male, 4 females; average time since flight: 377 days) on a Sensorimotor Disorientation Analog (SDA) that would mimic their postflight experience and functional performance following long duration stay in microgravity. We chose to replicate two timepoints during postflight recovery that would encompass a large range of performance decrements: immediately after landing (R+0-4hrs; high level) and post-landing (R+24-48hrs; low level). The SDA consisted of galvanic vestibular stimulation (GVS) to disorient the vestibular system, visual disorientation goggles to disrupt the visual field, and a weighted suit to alter proprioceptive feedback and replicate subjective heaviness. A random sum-of-sines profile between 0-1Hz was used for the GVS with peak amplitudes ranging from 1-4mA (Wood, 2002). GVS was applied independently first at the low (2mA) and high (3mA) levels, followed by the weighted suit alone at the low (20% body weight) and high levels (40% body weight), then combined with the GVS. Last, the disorientation goggles were applied alongside both the GVS and weighted suit at the low (0.07-0.10+ blood alcohol content (BAC)) and high (0.12-0.15+ BAC) levels. Each element of the SDA could be increased or decreased depending on crew feedback to find the disorientation levels that best matched their experience.

Four of the five crewmembers reported that GVS alone replicated ~80-90% of their post-flight performance with the weighted suit fine-tuning the experience to replicate an additional 5-10% of their experience. The fifth crewmember stated the GVS and weighted suit equivalently replicated their experience (50%). Crewmembers did not believe the disorientation goggles represented either the visual disruptions or illusory sensations that they experienced postflight, nor did they believe the goggles impacted their performance in postflight tasks similarly. While the disorientation goggles were not meant to replicate the exact visual disruptions that have been described by crewmembers, the feedback suggested that replicating crewmember experience is important. The final SDA, resulting from crewmember feedback, includes the GVS at the levels described above and the weighted suit at 15% and 30% body weight. The disorientation goggles were removed from the SDA. These results provided a more accurate SDA that can be used to define the sensorimotor assessment thresholds. The results from this exploratory study were presented at the 2023 NASA Human Research Program (HRP) Investigators' Workshop (Moudy et al., 2023).

Aim 1b: The second study was completed to validate the SDA levels defined in Aim 1a by confirming that 1) three distinct groupings exist in task performance for the three SDA levels, and 2) the range of performance across the three SDA levels replicates the range in postflight performance of crewmembers. Thirty healthy non-astronaut subjects (17 male, 13 female) performed three tasks, termed gold standard measures, that have a wealth of spaceflight data available where the recovery timeline is understood. These tasks included computerized dynamic posturography (CDP), obstacle walk, and tandem walk. CDP is the only neurovestibular medical requirement (MedB 1.5) to quantitatively assess balance recovery in which we have a wealth of data through the Shuttle and International Space Station (ISS) programs. Subjects were asked to maintain upright stance for 20s with eyes closed on an unstable sway-reference platform that pitches in proportion to body sway (EquiTest system; Natus, San Carlos, CA). This was performed with head erect (sensory organization test (SOT)-5) and with head pitch ±20° to an auditory cue (SOT-5M). An equilibrium score (EQ) measured from peak-to-peak anterior posterior sway provided an overall stability score (Wood et al., 2012). Obstacle walk and tandem walk tasks are well-established measures from recent investigations including Field Test and Standard Measures (Clément et al., 2022; Reschke et al., 2020). The obstacle walk is a modified timed-up-and-go task involving a sit-to-stand with 10s quiet stance followed by walking to and around a cone placed 4m away while navigating a 30cm obstacle on the way to the cone and back. The tandem walk involves walking heel-to-toe for approximately 10-12 steps with eyes open and eyes closed. Subjects performed the gold standard measures under each level of the SDA.

As SDA magnitude increased, overall performance outcomes decreased. However, the ability of the SDA to replicate the range of astronaut postflight performance was task dependent. CDP SOT-5 performance across SDA levels closely replicated astronaut performance preflight and postflight at R+0-24hours and R+24-48hours. SOT-5M, however, had minimal performance changes across SDA levels and was unable to replicate astronaut performance potentially due to 1) a learning effect for this complex task that mitigated effects from the SDA, and/or 2) the medial-lateral GVS disruption was mitigated by either out-of-plane head pitch movement or high cognitive effort. The obstacle walk showed performance changes across SDA levels and matched astronaut performance preflight and at R+24-48hrs . Obstacle walk performance when SDA was at the high level (mimicking R+0-4hrs) was reduced in comparison to the low level (R+24-48hrs); however, it was not replicative of astronaut performance immediately after landing. Specifically, crewmembers take longer to turn around the cone and for the turn to sit back in the chair at the end of the task. This specific disruption was unable to be replicated using the SDA modalities. For example, both the GVS and weighted suit are consistent disruptions, whereas crewmembers will feel increased disruption during head movement (such as turning or standing from a chair). Last, tandem walk had distinct groupings of performance across SDA levels and was able to elicit a high level of disorientation consistent with R+0-24 hours postflight performance for eyes open and eyes closed. The low-level SDA for both eyes open and eyes closed was more disruptive than previous crewmember performance at the R+24-48 hours timepoint. These results suggest that the SDA levels are able to elicit distinct performance groupings and, although not able to perfectly replicate R+0-4hrs, the SDA did replicate a large range of performance after return to Earth.

Aim 1c: This sub-aim was removed from the proposal. The initial intent of Aim 1c was to examine a large number of proposed sensorimotor assessment tasks in an effort to reduce the set of tasks to those that are the most sensitive to changes in sensorimotor disruption via the SDA (i.e., vary as a function of SDA magnitude). This reduced set of proposed tasks would then be used in Aim 2 to map performance against operational performance measures and Aims 3-4 under different analog conditions. However, this early reduction of potential sensorimotor assessment tasks was based on changes in performance between SDA levels alone, which may not be reliable for certain types of movements as found in Aim 1b. Further, the ultimate goal of this research is to map sensorimotor assessment performance to operational task performance. Therefore, sensorimotor assessment tasks should only be removed if they do not predict performance in operational tasks. As such, all proposed sensorimotor assessment tasks will be performed under each analog condition in the following aims alongside operational tasks.

Aim 2: This aim seeks to map performance in a proposed set of sensorimotor assessment tasks with performance in operational tasks. In discussions with the NASA Flight Operations Directorate and feedback from a Technical Interchange Meeting sponsored by the HRP Health Human Countermeasures Element, the proposed set of sensorimotor assessment tasks should aid in progressive adaptation to the novel gravitational environment, provide opportunities to develop strategies to recover from off-nominal body positions, and mimic operational tasks such that crewmembers can self-assess their potential ability to complete their missions. This aim will also utilize high-fidelity operational tasks that were developed to simulated capsule egress and early exploration EVA (Egress Fitness, PI: Norcross). (Ed. Note: See "Validation of Fitness for Duty Standards Using Pre- and Post-Flight Capsule Egress and Suited Functional Performance Tasks in Simulated Reduced Gravity", Internal Project, PI: Norcross). Data collection of an initial 20 subjects is currently in progress, at which time interim statistical analysis will be completed to determine the number of additional subjects needed to determine the relationship between task sets.

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