Safe Exploration: Sensorimotor Assessments for Early Extravehicular Activities

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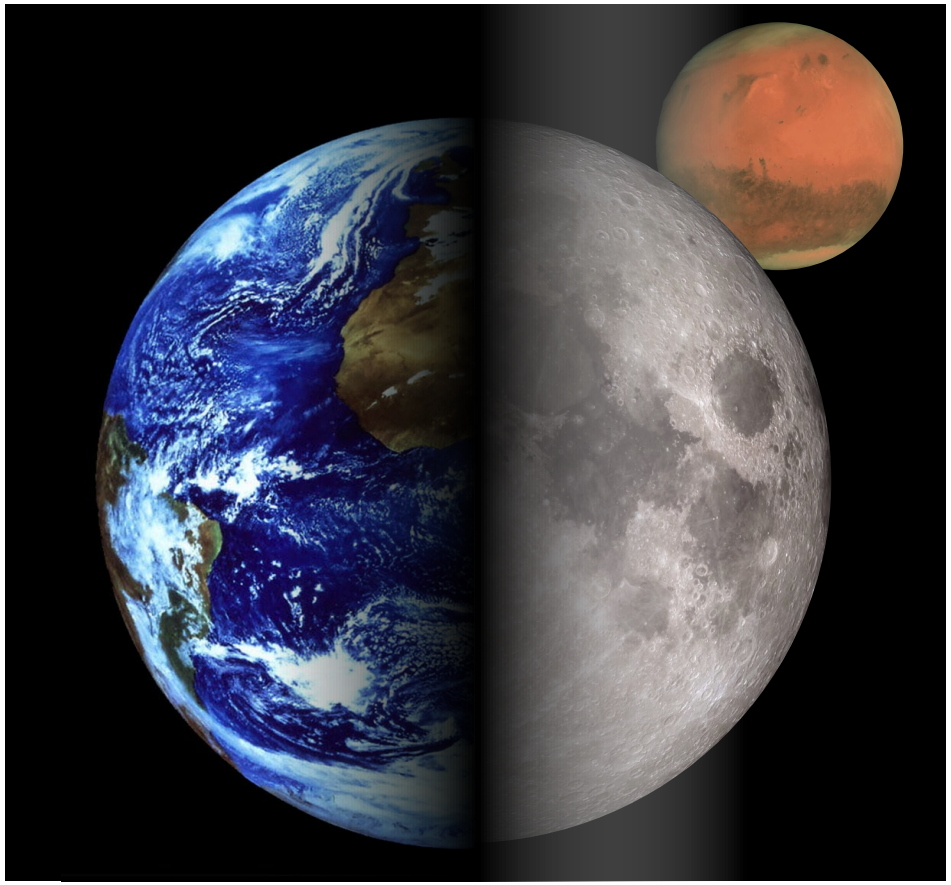

Disclosure Information

94th Annual Scientific Meeting

I have no financial relationships to disclose.

I will not discuss off-label use and/or investigational use in my presentation.

Introduction

- Exploration class missions will require a new level of autonomy around periods of gravitational transition, when sensorimotor disturbances are known to be significant.

- The operation
return to Eart
medical interv
as needed will not be available after landing on the lunar or Martian surface.

- Developing sensorimotor assessments will help inform crew preparedness soon after gravitational transitions prior to EVAs.

Purpose

To define and validate a set of sensorimotor assessment tasks using ground-based analogs

Defining Task Requirements

Task requirements developed based on lessons learned from Apollo, and conversations with flight surgeons, astronaut representatives, Astronaut Strength Conditioning and Rehabilitation team, and relevant subject matter experts.

- Capability for self-administration and self-assessment
  - Assessment tasks should be easy to understand and complete individually and/or with another crewmember
  - Task outcome measures should be easily interpretable by crew and flight surgeons with performance thresholds available*
- Aid in progressive adaptation to the novel gravitational environment
  - The level of sensorimotor disruption is unknown with the longer transit times for Artemis missions
  - Tasks should be ordered from least to most provocative of the sensorimotor system (Rosenberg et al. 2022)
- Provide adaptation opportunities to develop strategies needed during EVAs
  - Tasks should mimic body movement utilized in operational tasks (e.g., kneeling, turning)
  - Tasks should provide opportunity to recover from off-nominal body positions

*Validation testing in 1G and with center of mass offload to lunar *g*

Defining Task Requirements

Logistic Constraints

- Space availability for Artemis III and IV is based on Starship HLS configuration/usable space
  - Assessment tasks should be completable within a limited space (e.g., one to two steps)
  - Tasks can expand or be modified to fit the space configurations

- Limited to no mass available for hardware
  - Minimize hardware required to complete tasks
  - Tasks should utilize available configuration (e.g., vertical stairs) or hardware (e.g., box), if needed

Proposed Assessment Tasks

1. Postural Challenge Task
2. Step Test
3. Fall Recovery Task
4. Four-Square Step Test
5. Obstacle Turn Task
6. Kneel-and-Turn Task
7. Augmented Reality Full-Body Eye-Hand Coordination

Subjective Monitoring:

- Motion Sickness (0-20)
- Physical Fatigue (0-9)
- Cognitive Demand (NASA TLX) (0-100)
- Illusory Sensations with Head Motion (0-4)

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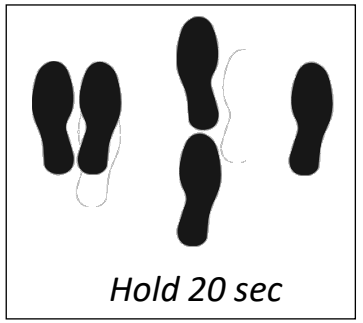

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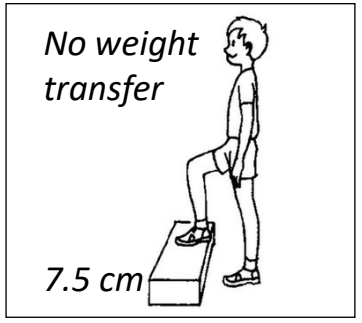

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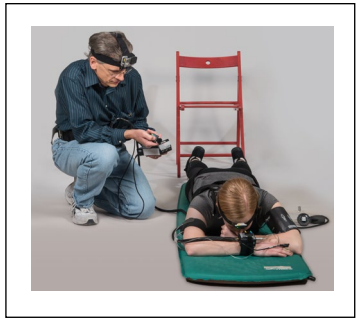

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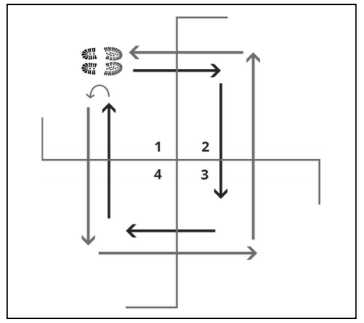

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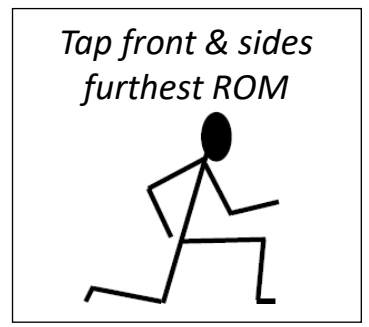

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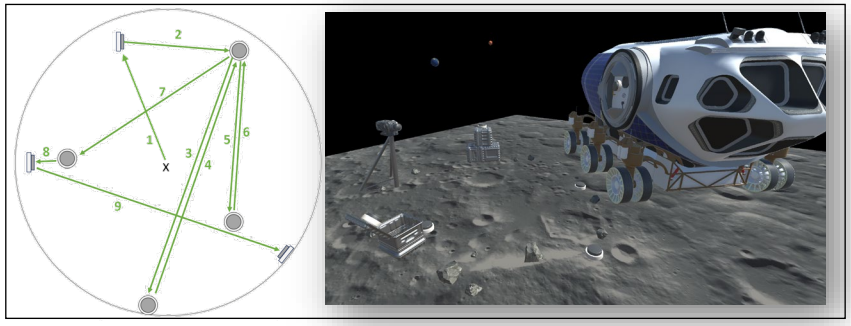
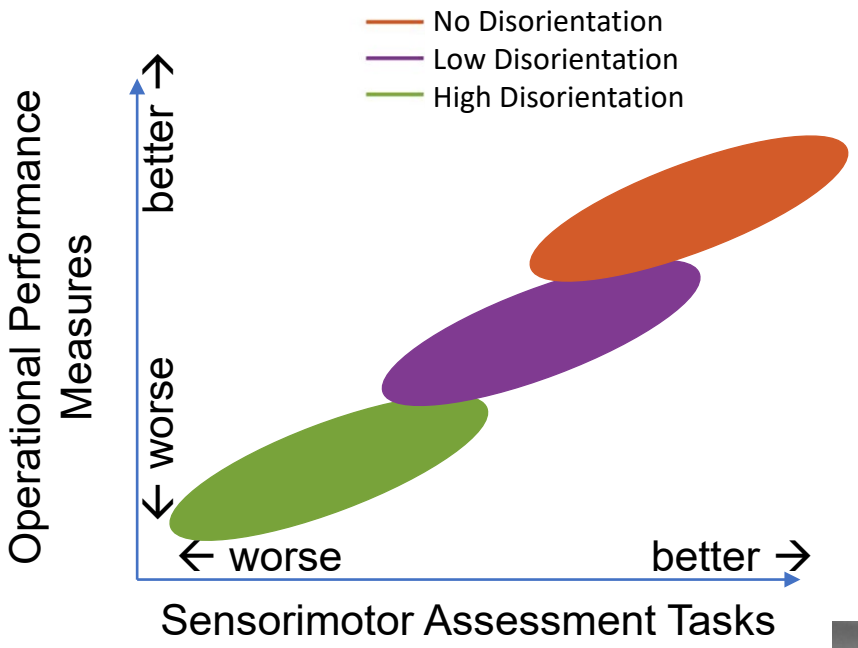


Validation Through Spaceflight Analogs



Validation and down select of assessment tasks is ongoing defined as 1) the most sensitive to changes in sensorimotor disruption and 2) correlated to performance in operational analog tasks

Spaceflight Analogs:

1. Developed a new portable sensorimotor disorientation analog (SDA) that can elicit various levels of disruption

2. +3G_x Centrifugation

3. Active Response Gravity Offload System (ARGOS) offloaded to lunar G

Spaceflight Analog: SDA

Sensorimotor Disorientation Analog

Contains:

- Galvanic Vestibular Stimulation
- Weighted Suit

Mimics:

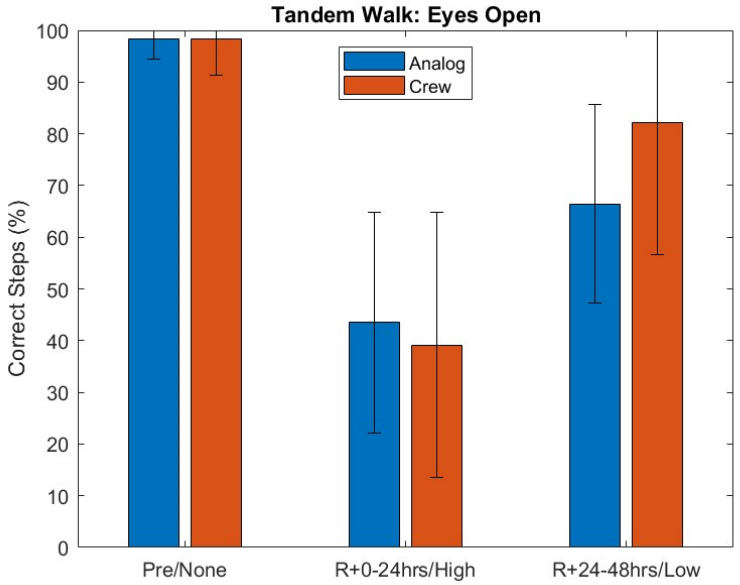
Astronaut postflight performance at

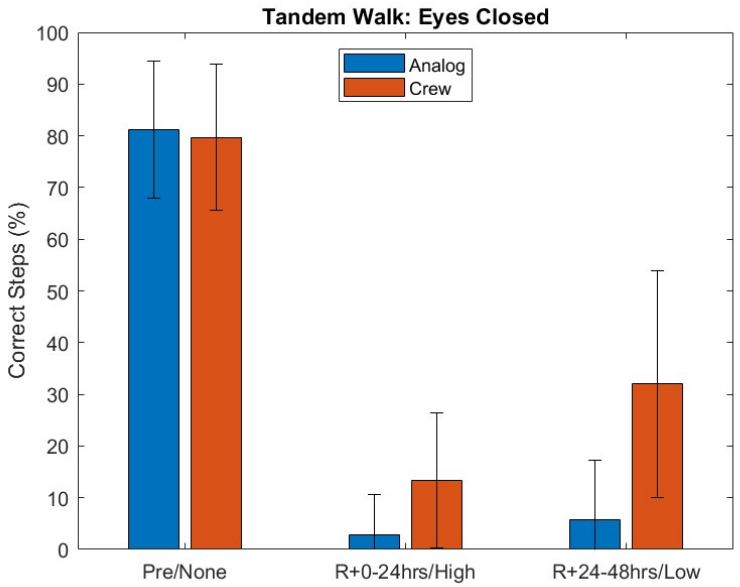
R+0-4 hours

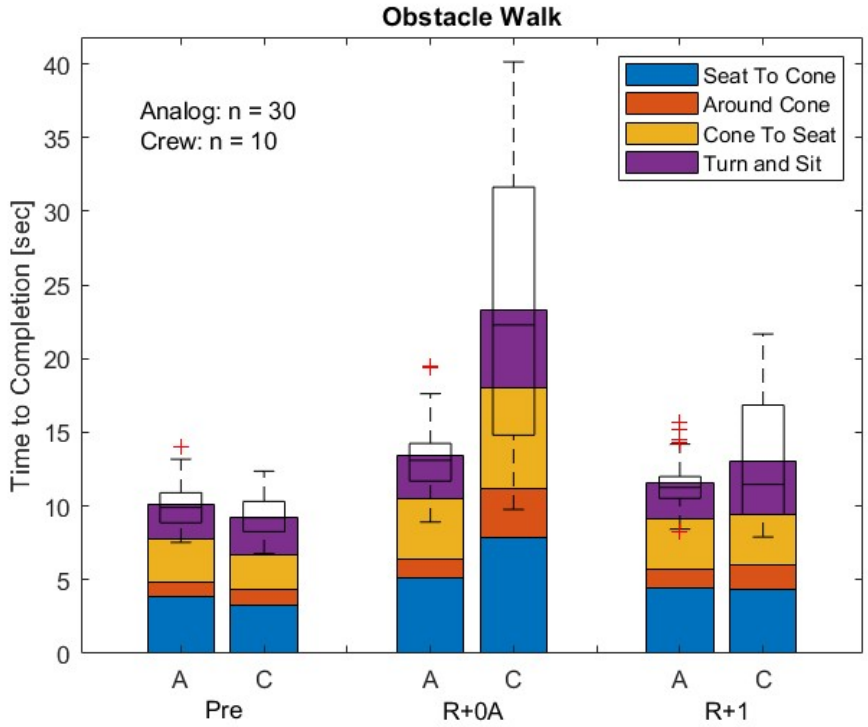
R+24-48 hours

- Purpose: Simulate the effects of readaptation to a gravitational environment after a prolonged period in microgravity
- Target the vestibular and proprioceptive systems
- Feedback from 5 previously flown crewmembers helped determine levels of disorientation for each element of the SDA
  - The final SDA was subjectively rated to replicate ~85% of their postflight experience and impact on performance
  - Tandem walk performance with the SDA was consistent with their postflight tandem walk performance encompassing the large range of variability between crewmembers

Spaceflight Analog: SDA







30 non-astronaut subjects performed the postflight tasks using the SDA

Overall, SDA does a good job at eliciting distinct performance levels, however, is not consistently able to capture the full variability seen at R+0.

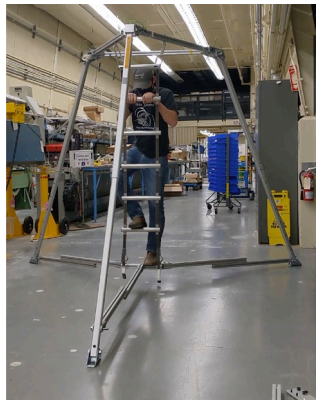
Spaceflight Analog: SDA

Purpose: Validation study using the SDA to define the tasks that are 1) the most sensitive to changes in sensorimotor disruption and 2) correlated to performance in operational analog tasks

Operational Tasks:
High-fidelity analogs of body movements during operation

1. Simulated Capsule Egress
   - Supine to stand in small area
   - Deployment and climbing vertical ladder with bag transfer
   - 25 ft traversal walk
2. Simulated EVA
   - Hatch egress navigation and ladder descent
   - Manual control task board
   - 5-min traversal transporting weighted bags across regolith

1.



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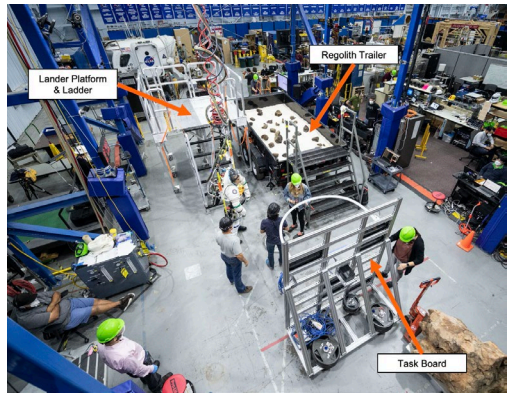
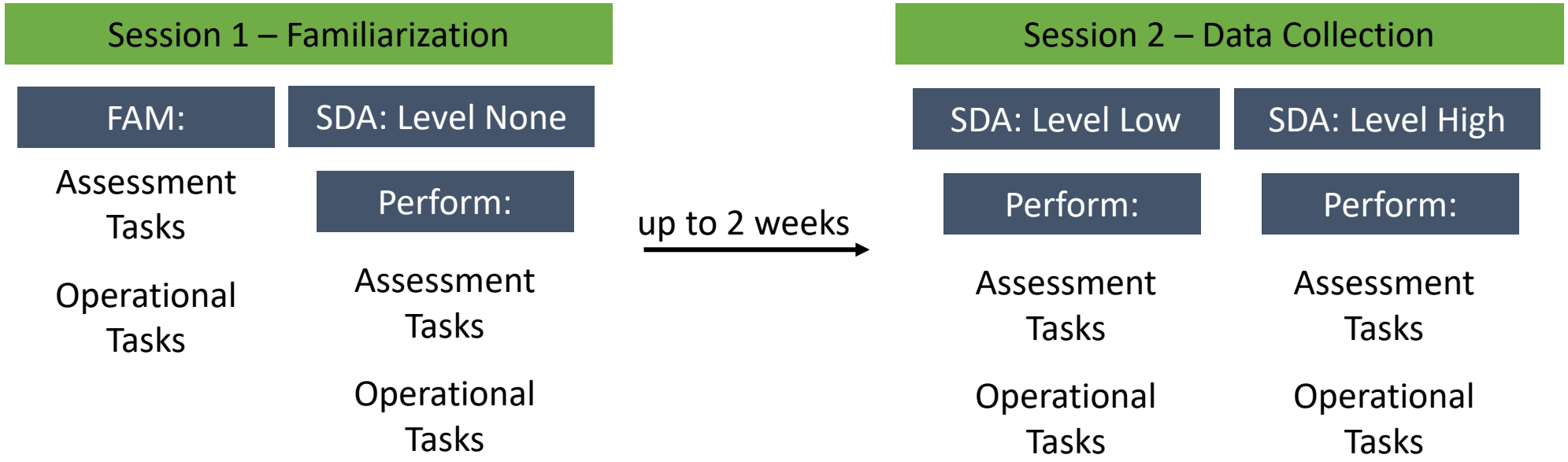


Joint EVA and Human System Mobility Test Team has opportunities to gather even higher-fidelity operational movements for validation of the sensorimotor assessment tasks

Spaceflight Analog: SDA

Methodology:

- n = 20 subjects completed
- Familiarization was used to minimize learning effects
- Data collection SDA levels were cross-balanced to minimize bias of fatigue effects



Spaceflight Analog: SDA

Initial Results:

- Obstacle Turn Task (OTT) and Fall Recovery from prone and supine had the strongest correlations across each operational task (except the task board)
- Significant differences between SDA levels were present for OTT and Fall Recovery

Interim analysis results required additional subjects to ensure performance thresholds are generalizable

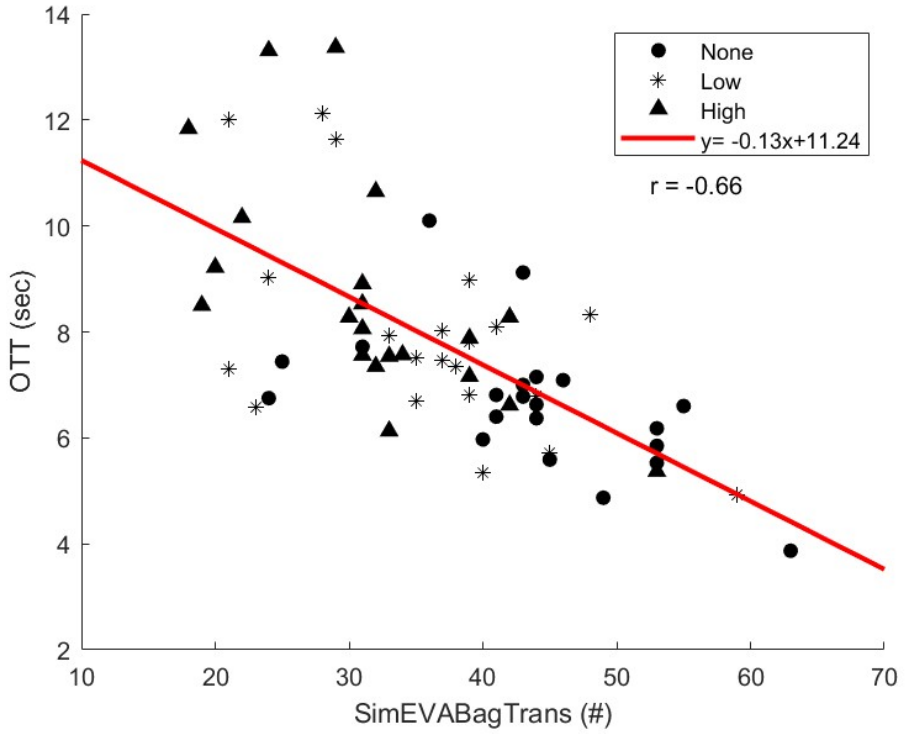
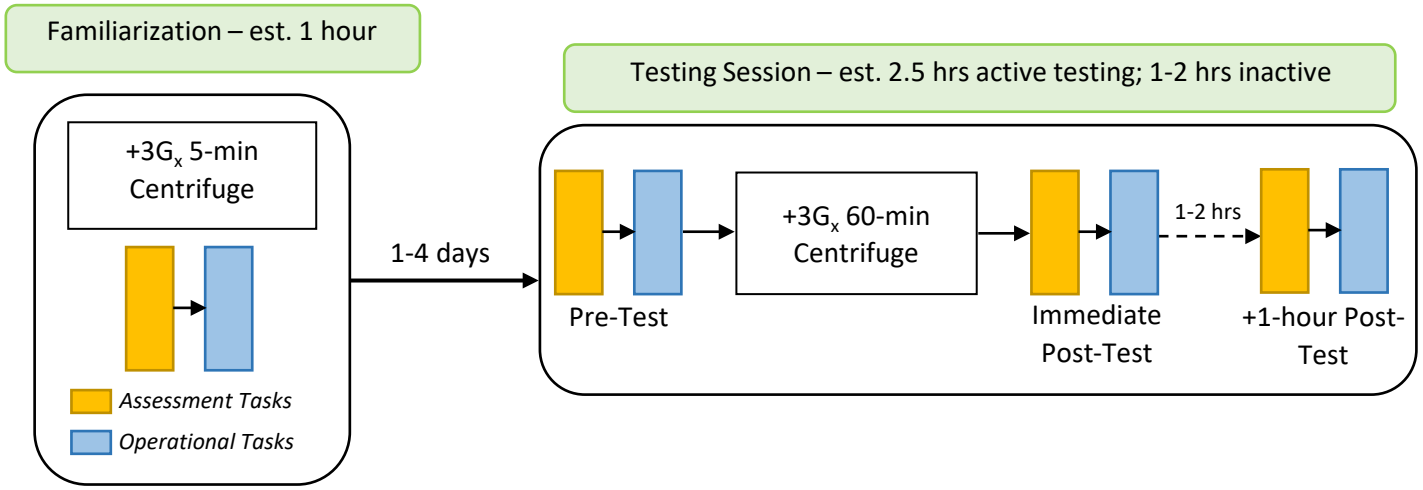


Table 1. Correlation r-values between performance in assessment tasks and operational tasks

Assessment Tasks	Operational Tasks			
	Egress Capsule	SimEVA Hatch	SimEVA Task Board	SimEVA Traversal
Step Test	-0.48	-0.6	-0.29	0.36
Fall Recovery-Prone	0.64	0.59	0.35	-0.57
Fall Recovery-Supine	0.63	0.62	0.28	-0.56
Four-Square-Step-Test	0.51	0.51	0.27	-0.44
Obstacle Turn (OTT)	0.67	0.7	0.33	-0.66
Kneel Turn	0.49	0.67	0.5	-0.5

Spaceflight Analog: +3G$_x$ Centrifugation

- Collaboration with KBR Aerospace and Environmental Protection Lab in San Antonio, TX
- Sustained hypergravity centrifugation for 60-min has been used to drive vestibular adaptive changes similar to post-spaceflight
- Subjects will be supine with feet pointed in the direction of motion so that the resultant force vector is in the naso-occipital direction to minimize orthostatic stress



Spaceflight Analog: ARGOS

- This validation would aid in defining lunar G performance thresholds
- Subjects would be suited for the operational tasks to increase fidelity
- Subjects would not be suited for the assessment tasks to mimic capsule/module shirt sleeve environment
- Potential opportunity to gather initial data in Martian G

Summary

- Exploration class missions will require crew to be able to self-assess and treat their sensorimotor dysfunction after gravity transitions, and in off-nominal situations they may be required to perform provocative, challenging tasks soon after landing

- The assessment tasks were defined based on lessons learned from Apollo and subject matter experts (e.g., flight surgeons, crew representatives, etc.) to include the following:
    1) Mimic body maneuvers such as reaching, bending over, etc. such that crew can self-assess their potential ability to complete operational tasks
    2) Provide opportunities to develop strategies to recover from off-nominal body positions
    3) Aid in progressive adaptation to the novel gravitational environment

- Validation is ongoing with certain assessment tasks doing well at predicting operational performance

Thank You!

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Neuroscience