Impacts on Cognitive Decay and Memory Recall during Long-Duration Spaceflight

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Agenda

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Project Overview

- The purpose of the research is to measure/characterize memory loss of previously trained tasks during simulated long-duration spaceflight (LDSF) mission.
- Four groups (composed of four-person teams) will spend 2-3 weeks in an isolated environment simulating the rigors of a long-duration space mission.
- Findings are expected to determine when refresher training should be provided during LDSF missions.
- Proposing 30-month longitudinal research study, using thirty-two subjects with similar education, experience, and skillsets
    - Recruited from UND's John D. Odegard School of Aerospace Sciences.
    - Subjects will be equally divided between a treatment group and a control group.
    - Subjects will participate in four experiment missions held during 2021-2022.
    - Each mission will include four informed subjects who have received individual and crew task training on several tasks, followed by practice and testing to establish a baseline for comparison when the task is repeated during simulated spaceflight.
    - During task crew member will wear a wireless 32-channel EEG skull cap measuring NeuroCognitive Performance (NCP)
    - Researchers will host virtual follow-up interviews at mission completion +30, +90, +180, +360, and lastly at +720 days.
- EEG data will be processed by MATLAB®, EEGLab®, eLORETA, NeuroCoach™, and SCCN neuroscience tools to develop a real-time predictive NeuroCognitive Profile (NCP
- The NCP will be used by IBM's SPSS 23 in producing statistical analysis using within & between groups 2x3 repeated measures Factorial ANOVAs and repeated measures MANOVA, Field, 2009; Baguely, 2012; Yigit, 2018)
- Surveys and questionnaires will be hosted on Qualtrics using Likert scale questions
- G*Power was used to determine an estimated power significance,
    - A medium effect size corresponds to a partial Eta-squared ($\eta p2$) .06 and Cohen's F 0.25 (Szucs, 2017 & Richardson, 2011, & Cohen, 1965, 1973, 1988).

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The Problem / Gap in Knowledge

- As we prepare to trek beyond the confines of our Moon, NASA has identified a critical knowledge gap:
    - How and what to train future long-duration spaceflight (LDSF) crew brfore flight
    - How, what, and when to retrain crews during
  - Given an estimated knowledge increase of two to three times current demands
  - And to oppose potential operational impact resulting from physiological, psychological and psychosocial efforts of LDSF and additional space stressors not already mitigated
- NASA's seeks solutions to several Human Research Roadmap risk and knowledge gaps in the following Technology Areas (TA):
  - TA: 7.5.1. Enhanced crew training and learning strategies and technologies
  - TA 11.3.4 – Simulation-Based Training and Decision Support System
    - Determining if proficiency is measurable using Rasmussen's Skills-Rules-Knowledge (SRK) cognitive states or attenuated by environmental stressors and task difficulty.
    - Illuminate if training needs for long-duration spaceflight training can be predicted.
- The required knowledge increase supporting crew autonomy result from a physics imposed communications latency (Antonietta-Viscio, 2014)
  - Expected to preclude readily available knowledge support and decision-making advice from NASA's Mission Control Center (MCC). (Vincenzi, 2009)
  - Never before in space exploration history has an orbiting crew operated fully autonomously without the MCC providing "overwatch" until now.

Problem / Research Complexity

Human Knowledge Capture, Application & Retention Problem
Worsened by Natural Aging , Illness and Disease

Astronauts Train reach and keep peek performance

International Space Station (ISS)

Commercial Space Crew

NASA Artemis

Long Duration Spaceflight (LDSF)

Outer Limits

LDSF Analog Self-Contained Facility

Simulated Stressors

Realistic Mission Activates

All Digital Environment

Mimic On-orbit Environment - Intermixed Activities (Mission, Cognitive, School, Personal Time)

Use EEG – Measuring Devices, Baseline Development

Measurements Recorded

Homologous Subject Pool

Identical Subjects (as practice)

Experiment Group (16)

Control Group (16)

Self-administered Cognitive Batteries

Pre- & Post-activities Surveys & Questionaries

Knowledge Rules Skills

Produced EEG based NeuroCognitive Profile (NCP)

Realistic Work Activities

NASA Funded Research Published by Dr. Jack Stuster (2018, 2019)

Sourced 8 Cognitively Depending, varying difficulty Tasks

Individual (4) and Crew (4)

Varying Time & Stress

SPSS Used for Statistical Analysis

Mission IX includes 4-Repeated Measures experiments. A Pilot Study and 3- full duration experiments

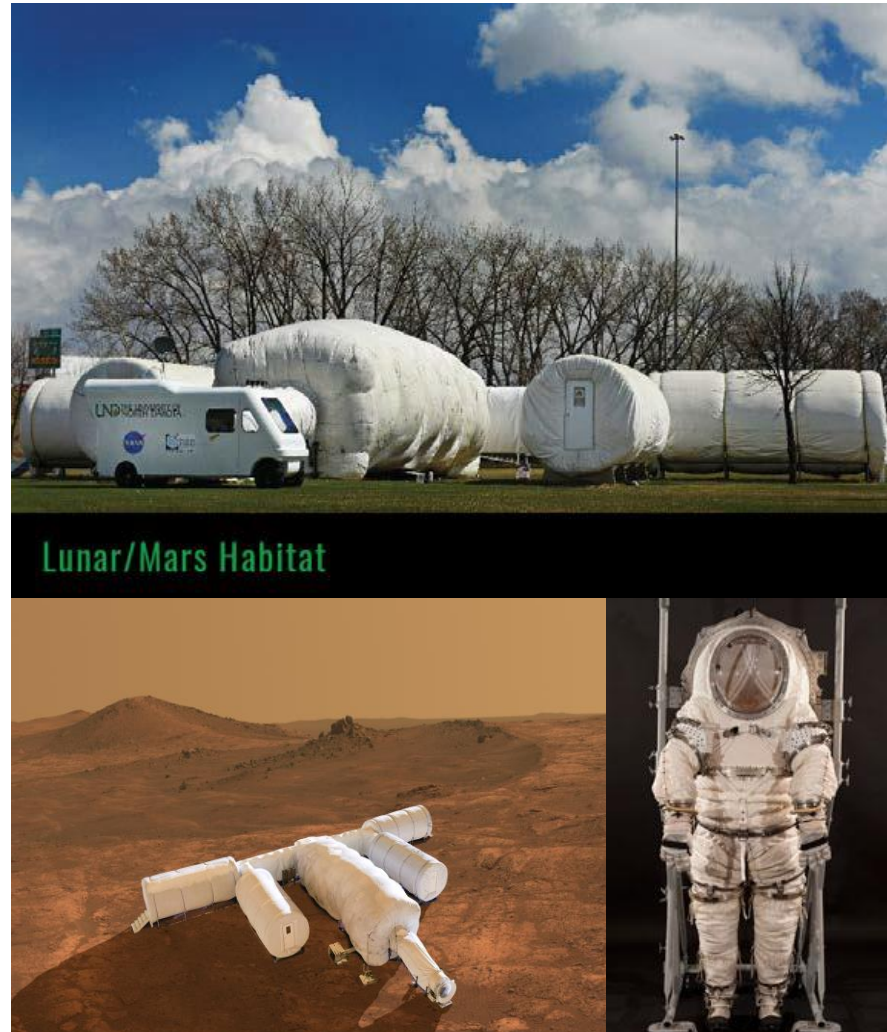
Publish

Research Problem

- Future LDSF will expose human crews to prolonged microgravity, Galactic Cosmic Radiation, and other stresses while living and working within an Isolation, Confined & Extreme (ICE) environment.
- These factors are expected to negatively impact the body's central nervous system, cognition, memory, and behavior.
  - The most effective process for mitigation is training
- Research is needed to comprehensively measure and model human cognitive decay and memory recall limitations in a spaceflight-realistic environment—the purpose of this research opportunity.

The Inflated Lunar/Mars Analog Habit

- This project extends previous work, exploring the development of human models of adaptive training and neuroplasticity for Isolated Confined Extreme (ICE) environments in the Inflatable Lunar/Mars Analog Habitat (ILMAH) on the UND campus.
- With an estimated volume of 15,000ft^3, the ILMAH provides an excellent resource, purposefully located for convivence and reach of resources
- ILMAH makes use of training versions of the UND developed NDX-2 planetary space suits and electric rover
- The habitat includes modules for maintenance, vegetable cultivation, physical fitness and human performance, geology research and mission control



Benefits

- Long Duration Space Missions
  - By determining cognitive decay rates, we will have a better understanding of the state of knowledge and when refresher training is truly needed
  - Support the design and scope of in-flight training systems
- Terrestral
  - Outcomes will help in pre-flight training design and planning as well as most effective use of training systems and simulators
  - Provide supporting evidence to medical and other industries treating traumatic brain injuries or illness
  - Lastly provide similar industries with tools needed to better train their personnel

Conclusion

- Predicting cognitive decay and memory recall enables:
  - Refresher training rate prediction
  - Identification and efficient use of valuable resources
  - Tailored training for specific learning needs
  - Reduction of time and cost of initial and refresher training
  - More complex and effective training development
- Results can also help those with cognitive impairment and decline; such as PTSD, ADD, Dementia, Alzheimer's and other memory loss or high cognitive decay conditions
- Approve this project for continuing to the next phase