

Countermeasures to Reduce Sensorimotor Impairment and Space Motion Sickness Resulting from Altered Gravity Levels

Completed Technology Project (2013 - 2017)



Project Introduction

The effect of altered gravity on astronauts' perceptions and motor skills is significant as it threatens the health, well-being, and performance of crews. Astronauts experience gravitational transitions from Earth's gravitational level during launch to microgravity in space, then to partial gravity if landing on the Moon, Mars, or Martian moons, followed by a return to microgravity, and finally re-entry back to Earth. In addition, the use of Artificial Gravity (AG) from an on-board centrifuge also presents an altered gravity challenge, in particular during transitions between gravity levels. During each of these g-transitions astronauts must adapt their sensorimotor programs to coordinate perceptual and motor capabilities and function successfully and safely. The ability to identify and predict changes in sensorimotor function during these g-transitions is essential to the development of protocols and countermeasure implementation for future crew members. This project takes a new approach which could lead to a practical and acceptable protocol. We alter gravito-inertial accelerations with centrifugation in different body orientations. Furthermore, we have quantified sensory adaptation capabilities of both perception and manual control ability to a transition into hypo-gravity. Additionally, we investigated the effect of a common motion sickness drug, promethazine, on basic vestibular motion perception. This is an important step in better understanding the benefits and risks associated with the use of motion sickness drugs in conjunction with adaptation training and in flight after critical gravity transitions.

Specific Aims: The original specific aims for this project were: SA1) Demonstrate that individual differences exist in the ability to adapt to gravitational transitions, and can be measured quantitatively by measures of subjective orientation, closed loop manual control, and subjective motions sickness reports. SA2) Test whether pre-training by adapting to one altered gravity environment can improve sensorimotor adaptation in another altered gravity environment. SA3) Test whether the leading pharmacological agent, promethazine, affects either basic vestibular perceptual function or the adaptation rate to an altered gravity environment and the associated motion sickness symptoms. SA4) Develop and test a combined pre-adaptation training and pharmacological intervention protocol that can both improve sensorimotor adaptation and reduce the associated motion sickness.

Hypotheses: The hypotheses are: H1) Individual differences exist in the ability to adapt to altered gravity environments and these differences can be predicted by measuring adaptability in one altered gravity environment. H2) Pre-adaptation training in one altered gravity environment will improve sensorimotor adaptation in another altered gravity environment. H3) Promethazine will reduce motion sickness, but will have no influence on either basic vestibular perceptual function or sensorimotor adaptation to altered gravity environments.

Results: We determine individual differences in performance of both the



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perception and manual control tasks in terms of initial performance decrement and adaptation time constant. All subjects consistently show a performance decrement in the perception and closed-loop manual control task on initial exposure to altered-gravity, followed by a return back to baseline performance. Promethazine significantly affects upright roll tilt motion perception thresholds, a measure of basic vestibular perceptual function. Thresholds were not different with promethazine for upright yaw or upright interaural translation motions. However, the small but consistent effect of promethazine on roll tilt perception could have functional and operational significance.

Deliverables: Deliverables are a methodology for measuring an individual's capacity to adapt to an altered gravity environment using affordable centrifuge tests, and a combined pharmacological and pre-adaptation training intervention to reduce the severity of motion sickness and sensorimotor impairment during gravitational transitions.

Anticipated Benefits

Sensorimotor function is altered during gravitational transitions, such as those that occur during spaceflight. Related space motion sickness also occurs regularly during gravity transitions and impacts performance and operations. Astronauts must remain functional during the critical mission phases that occur during or are temporally close to gravity transitions, particularly for vehicle control and landing tasks. This project presents an experimental approach. It is aimed at a better understanding of perception and performance changes due to altered gravity using a centrifuge to change the G-level. Additionally, this project investigated whether there were detrimental effects on sensorimotor performance due to the administration of promethazine, a common motion sickness drug given during spaceflight to better handle gravity-transitions. Understanding sensorimotor impairment in altered gravity environments is also relevant for Earth applications. For example, it is important to understand how altered gravity exposure affects pilot performance, including perception and manual control, since the consequences of delayed or inadequate adaptation could be catastrophic. In addition, sensorimotor rehabilitation is critically important here on Earth for elderly and patient populations. Our findings on sensorimotor adaptation to altered gravity will likely be translatable to the learning and adaptation required during sensorimotor rehabilitation. Understanding sensorimotor adaptation mechanisms, enhancing adaptive rates, and being able to identify individuals who may have trouble with sensorimotor adaptation are all important topics for sensorimotor rehabilitation patients here on Earth.

Organizational Responsibility

Responsible Mission Directorate:

Human Exploration and Operations Mission Directorate (HEOMD)

Lead Organization:

National Space Biomedical Research Institute (NSBRI)

Responsible Program:

Human Research Program

Project Management

Program Director:

William Paloski

Principal Investigator:

Laurence R Young

Co-Investigators:

Daniel Merfeld
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Charles Oman
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Primary U.S. Work Locations and Key Partners

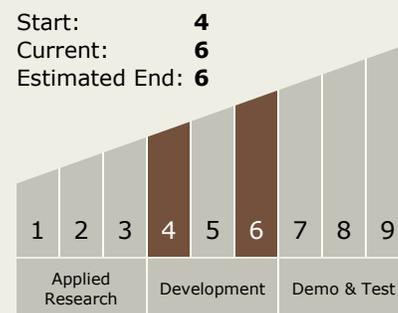
Organizations Performing Work	Role	Type	Location
National Space Biomedical Research Institute(NSBRI)	Lead Organization	Industry	Houston, Texas
Massachusetts Eye and Ear Infirmary	Supporting Organization	Industry	
Massachusetts Institute of Technology(MIT)	Supporting Organization	Academia	Cambridge, Massachusetts

Closeout Summary

We completed analysis of a double-blind, within-subject study to compare vestibular perceptual thresholds with the administration of promethazine and placebo. Roll tilt thresholds were found to be 31% higher after ingestion of promethazine ($p = 0.005$). We believe that these findings are an important first step in understanding implications of motion sickness drug administration during critical and demanding mission phases. Using a short radius centrifuge, we created a land-based hypo-gravity analog test paradigm. We developed the test protocol, conducted pilot testing, and tested 10 subjects in our altered-gravity perception test protocol. Analysis to date has revealed that subjects underestimate their roll angles when tilted in hypo-gravity compared to their baseline 1 G perception (mean gain diff = -0.27, $p=0.006$). After approximately 45 minutes in the hypo-gravity environment, subjects' motion perception returned to their 1 G baseline showing that subjects were able to adapt to the altered-gravity environment. Data analysis is currently being finalized and preparation of the associated manuscript is underway.

We also developed, pilot tested, and conducted a full manual control experiment using a short radius centrifuge and a human in the loop feedback control system. We found that both the RMSE and variability in the nulled chair position increased when subjects transitioned into the hypo-gravity environment, representing a worsening in the ability to perceive and null out passive roll tilt motions. Metrics related to the control strategies of the subjects, such as operator gains and control lags are currently being examined. From this ongoing analysis we hope to provide insight into changes in operational control strategies between the various gravity conditions, results that should be relevant to piloting performance during human controlled flight.

Technology Maturity (TRL)



Technology Areas

Primary:

- TX06 Human Health, Life Support, and Habitation Systems
 - └ TX06.3 Human Health and Performance
 - └ TX06.3.2 Prevention and Countermeasures

Target Destinations

The Moon, Mars

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Stories

Abstracts for Journals and Proceedings
(<https://techport.nasa.gov/file/60624>)

Abstracts for Journals and Proceedings
(<https://techport.nasa.gov/file/60630>)

Abstracts for Journals and Proceedings
(<https://techport.nasa.gov/file/60623>)

Abstracts for Journals and Proceedings
(<https://techport.nasa.gov/file/60631>)

Abstracts for Journals and Proceedings
(<https://techport.nasa.gov/file/60642>)

Abstracts for Journals and Proceedings
(<https://techport.nasa.gov/file/60613>)

Abstracts for Journals and Proceedings
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Abstracts for Journals and Proceedings
(<https://techport.nasa.gov/file/60638>)

Abstracts for Journals and Proceedings
(<https://techport.nasa.gov/file/60625>)

Articles in Peer-reviewed Journals
(<https://techport.nasa.gov/file/60616>)

Articles in Peer-reviewed Journals
(<https://techport.nasa.gov/file/60619>)

Articles in Peer-reviewed Journals
(<https://techport.nasa.gov/file/60629>)

Articles in Peer-reviewed Journals
(<https://techport.nasa.gov/file/60639>)

Articles in Peer-reviewed Journals
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Articles in Peer-reviewed Journals
(<https://techport.nasa.gov/file/60615>)

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Articles in Peer-reviewed Journals
(<https://techport.nasa.gov/file/60617>)

Articles in Peer-reviewed Journals
(<https://techport.nasa.gov/file/60620>)

Awards
(<https://techport.nasa.gov/file/60614>)

Dissertations and Theses
(<https://techport.nasa.gov/file/60643>)

Dissertations and Theses
(<https://techport.nasa.gov/file/60644>)

Papers from Meeting Proceedings
(<https://techport.nasa.gov/file/60640>)

Papers from Meeting Proceedings
(<https://techport.nasa.gov/file/60627>)

Papers from Meeting Proceedings
(<https://techport.nasa.gov/file/60641>)

Papers from Meeting Proceedings
(<https://techport.nasa.gov/file/60633>)

Project Website:

<https://taskbook.nasaprs.com>