Fiscal Year:	FY 2016	**Task Last Updated:**	FY 12/28/2016
PI Name:	Young, Laurence R. Sc.D.		
Project Title:	Countermeasures to Reduce Sensorimotor Impairment and Space Motion Sickness Resulting from Altered Gravity Levels		
Division Name:	Human Research		
Program/Discipline:	NSBRI		
Program/Discipline--Element/Subdiscipline:	NSBRI--Sensorimotor Adaptation Team		
Joint Agency Name:		**TechPort:**	Yes
Human Research Program Elements:	(1) **HHC**:Human Health Countermeasures		
Human Research Program Risks:	(1) **Sensorimotor (SM)**:Risk of Impaired Control of Spacecraft, Associated Systems and Immediate Vehicle Egress Due to Vestibular/Sensorimotor Alterations Associated with Space Flight		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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Zip Code:	02139-4301	**Congressional District:**	8
Comments:			
Project Type:	GROUND	**Solicitation:**	2012 Crew Health NNJ12ZSA002N
Start Date:	08/01/2013	**End Date:**	05/31/2017
No. of Post Docs:	1	**No. of PhD Degrees:**	2
No. of PhD Candidates:	3	**No. of Master' Degrees:**	1
No. of Master's Candidates:	1	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	1	**Monitoring Center:**	NSBRI
Contact Monitor:		**Contact Phone:**	
Contact Email:			
Flight Program:			
Flight Assignment:	NOTE: End date changed to 05/31/2017 per NSBRI (Ed., 3/6/17)		
Key Personnel Changes/Previous PI:			
COI Name (Institution):	Merfeld, Daniel (Massachusetts Eye and Ear Infirmary) Oman, Charles (Massachusetts Institute of Technology) Karmali, Faisal (Massachusetts Eye and Ear Infirmary) Priesol, Adrian (Massachusetts Eye and Ear Infirmary)		
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Task Description:

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 during launch from Earth's gravitational level 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 protocol development and countermeasure implementation for future crew members. This project takes a new approach which could lead to a practical and acceptable protocol for measuring sensorimotor responses in a hypo-gravity environment. By using the gravito-inertial alterations possible with centrifugation in different body orientations 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, an important scientific step in better understanding the benefit and risks associated with the use of motion sickness drugs in conjunction with adaptation training and in flight after critical gravity transitions.
The original specific aims and hypothesis 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. Data analysis shows individual differences in performance of both the perception and manual control task in terms of initial performance decrement and adaptation time constant. Apart from individual differences, 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.

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. To date, one important finding is that promethazine has a small but significant effect on 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. The small but consistent effect of promethazine on roll tilt perception could have functional and operational significance.

SA4) Develop and test a combined pre-adaptation training and pharmacological intervention protocol that can both improve sensorimotor adaptation and reduce the associate motion sickness. 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.

Deliverables include 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.

Rationale for HRP Directed Research:

Research Impact/Earth 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 aimed at better understanding 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 predict individuals who may have trouble with sensorimotor adaptation are all important topics for sensorimotor rehabilitation patients here on Earth.

Task Progress:

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 tilts when put into 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 have completed the majority of the data analysis for this study, and have 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.

Finally, we collected additional motion threshold data from subjects who were involved in our centrifugation studies. With this additional data, we were able to make statistical comparisons between basic vestibular function as estimated by motion thresholds and functional control in altered-gravity environments, as described by various metrics of manual control ability. We have completed data analysis for this study and found a positive, linear correlation between manual control variability and vestibular thresholds ($p < 0.01$) in the 1.0 GZ baseline condition. This suggests that sensory precision is a limiting factor in manual control performance. Additionally, manual control performance was 12.7% lower in 1.33 GZ ($p < 0.05$) and 37.5% higher in 0.5 GZ ($p < 0.05$), as compared to 1 GZ. Preparation of the associated manuscript is underway.

Bibliography Type:	Description: (Last Updated: 04/10/2019)
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